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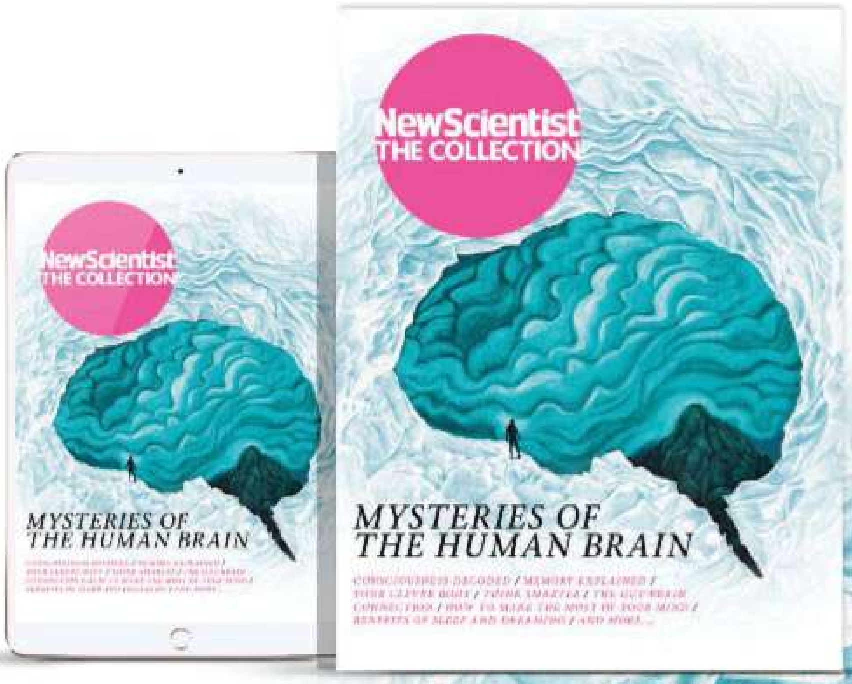

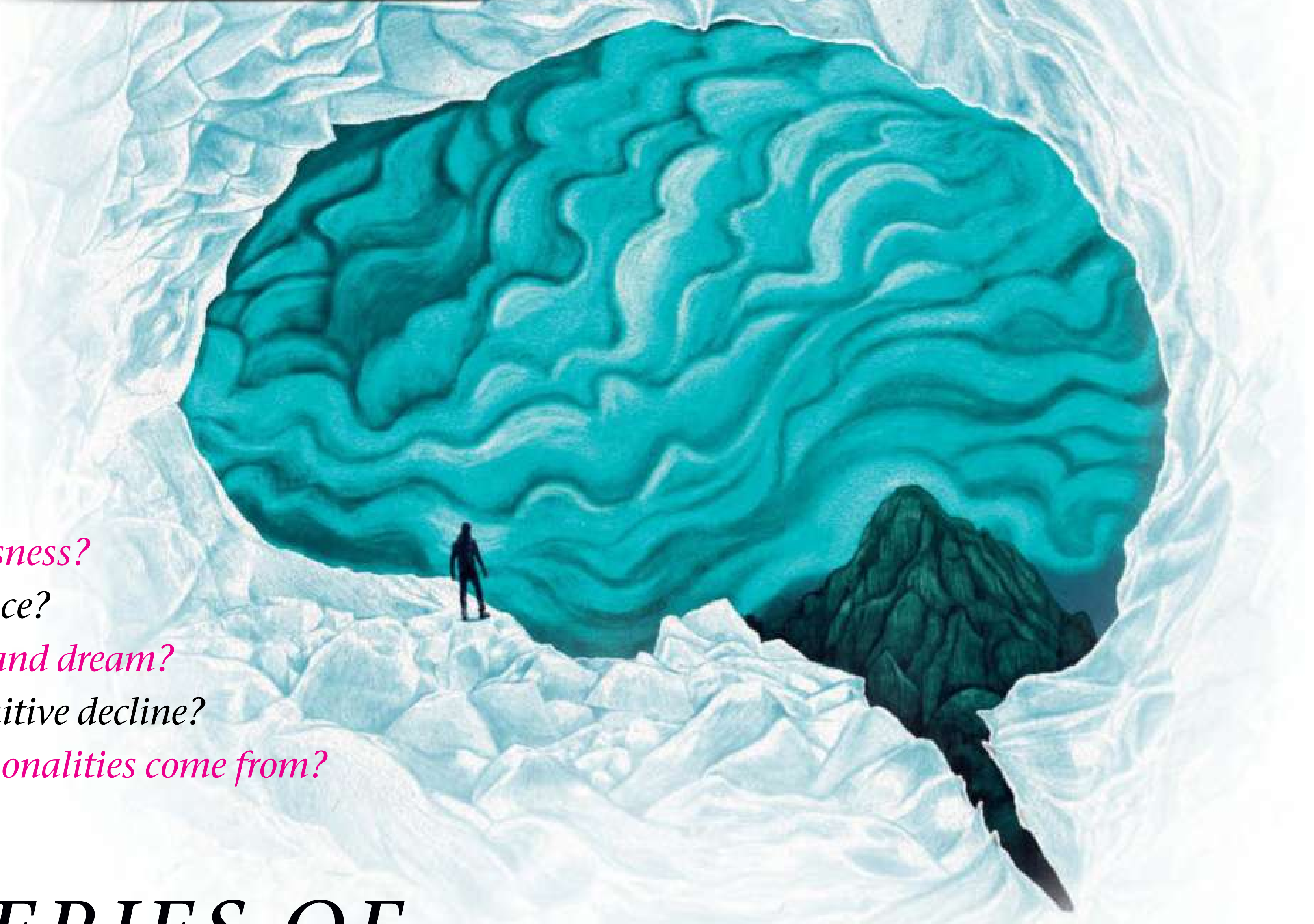

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Put it to the test

To see if "Veganuary" makes a difference, we (once again) turn to self-experimentation

GREGOR MENDEL had his pea plants. Ivan Pavlov had his dogs. At *New Scientist*, we have our staff, and every so often we like to experiment on ourselves – in pursuit of greater knowledge, of course.

Perhaps our most triumphant episode of self-experimentation came in November 2013, when 14 of our staff trooped into a London hospital looking unusually sober. A doctor told them: "You're going to be very excited."

For the previous month, they had been part of a pilot study to test whether a month off alcohol – Dry January as public health groups promote it – could really make a difference to your health. The results were surprisingly stark: scans showed that liver fat, whose build-up can damage the organ, dropped by 15 per cent on average among the 10 volunteers who gave up booze for the month, while there was no change for the four participants who drank as usual.

The study hinted that even short periods of behavioural change can have important effects, and highlighted the need for better evidence on this question of public interest. It spurred the researchers to keep on investigating.

> "Our most triumphant experiment came when 14 of our staff trooped into a hospital looking unusually sober"

A similar opportunity now presents itself. You may hear plenty in the coming weeks about the merits of "Veganuary", a month without eating animal products to benefit your health and that of the planet. It is an idea we welcome. There is no doubt that dropping meat and dairy is one way that individuals can meaningfully lower their carbon footprint, and long-term observational studies do suggest that vegan diets can be a boon for your health.

But going vegan is no cakewalk. Giving up staple foods and daily comforts like milk in your tea can be a wrench, and it can take careful planning to ensure you get all the nutrients you need. So, can short bouts of vegan eating yield any real benefits? To find out, 19 *New Scientist* staff gave veganism a go – with some unexpected results (see page 32).

In 2018, the researchers behind our Dry January study published the results of a larger version with more participants, confirming and expanding on those initial findings. We hope our modest Veganuary study might eventually prompt something similar. ■

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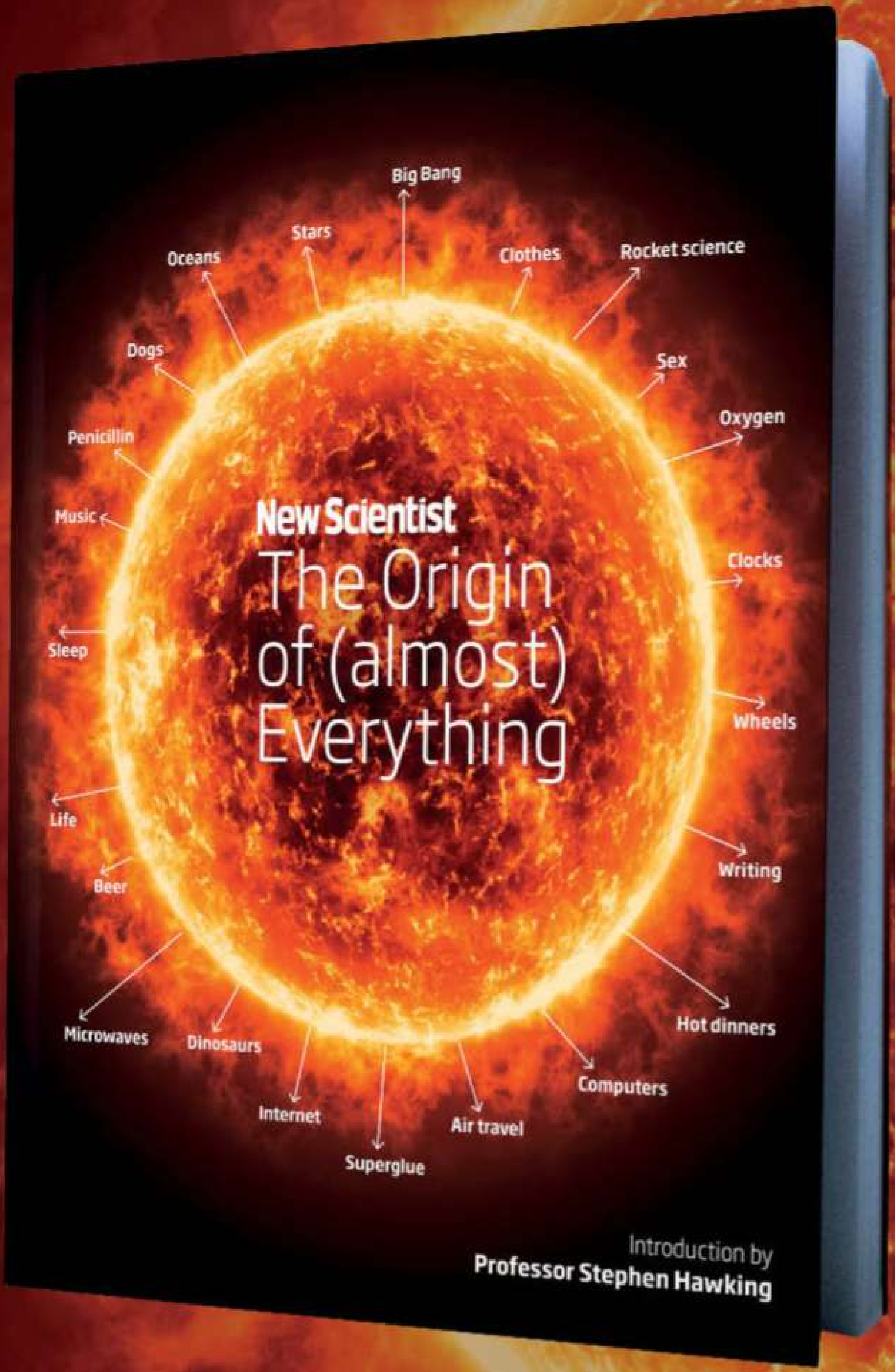
Where did we come from?
How did it all begin?



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Light therapy improves some symptoms **p8**

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They are here. But what are they really for? **p10**

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TERRY RENNA/AP/SHUTTERSTOCK

Starliner launches from Cape Canaveral in Florida

Spacecraft goes awry

Boeing's Starliner had to land prematurely during a recent test, which may delay US ambitions for crewed space flight, reports **Leah Crane**

BOEING'S Starliner spacecraft has faced a rough start. A software issue during launch meant it didn't supply the International Space Station as planned. It isn't yet clear what this will mean for US plans for crewed space flight.

The issue started before launch when Starliner's software latched onto the wrong clock to set its time. Nobody noticed this and its clock was 11 hours off what was intended as a result. About 31 minutes after Starliner launched, it fired its thrusters too early, using up fuel it needed to reach the ISS. So the Boeing team had to bring the craft back down for a landing in New Mexico on 22 December, which went smoothly.

During the landing, the spacecraft endured temperatures upwards of 1600°C. This was a crucial part of the test flight, which was planned to be the last before a crewed test in 2020. When *New Scientist* went to press, it wasn't clear whether the crewed test will proceed as planned or if another uncrewed test flight will be added to the schedule.

"Boeing, until we look at all that data, is not in a position to propose going to do a crewed flight test," said Boeing's Jim Chilton in a press conference. Reviewing data from Starliner's flight could take months.

NASA has contracted Boeing and Elon Musk's SpaceX to build capsules to carry astronauts to the ISS, but both have faced significant delays in the past few years.

Any further delays in crewed flights could pose problems for NASA, which currently has to purchase expensive seats aboard Russian Soyuz craft to get astronauts to the ISS.

"Further delays in the Commercial Crew Program unfortunately means NASA will continue to be reliant on its Russian partner to fly NASA astronauts to the ISS," says space consultant Laura Forczyk.

Flying humans to space from US soil is a feat that hasn't been achieved since the Space Shuttle programme ended in 2011. It now looks like the US may have to wait even longer. ■

Environment

Delay to ozone recovery expected

THE permanent closure of the ozone hole over Antarctica is likely to be delayed by the illegal production of the gas CFC-11 in China.

The ozone hole, which is usually open between September and November, is expected to recover by around 2060. But a modelling study now suggests that, in the worst case scenario, ozone recovery will be delayed by 18 years if the production of trichlorofluoromethane (CFC-11), used to make fridge insulation, continues unabated.

"The ozone hole over Antarctica is expected to recover by around 2060"

But such an extreme scenario is unlikely as there are signs that authorities in China have begun cracking down on the problem. If production is phased out over the next decade, which seems more likely, the result would be a two-year delay in ozone recovery, says Martyn Chipperfield at the University of Leeds, UK.

Were CFC-11 production to stop immediately, there will be virtually no impact on ozone recovery, according to his team's work (*Nature Communications*, doi.org/dhms).

That's because the rise in CFC-11 emissions between 2013 and 2017 wasn't enough to have a large impact among all the other factors that affect ozone recovery. ■ Adam Vaughan

Physiology

Endometriosis clue

A new understanding of the origins of endometriosis may lead to different types of treatment, reports **Jessica Hamzelou**

ONE IN 10 women live with endometriosis, but we still don't know its exact cause. New evidence suggests that some cases may be present from birth, and that different subtypes of the condition may benefit from different treatments.

Endometriosis is diagnosed when endometrial cells from the lining of the uterus are found elsewhere in the body. When people with the condition menstruate, these patches of cells, wherever they are, bleed. This is thought to be at least partly responsible for the debilitating pain people with endometriosis often experience, although we still don't really know. Those affected often find it harder to conceive, too.

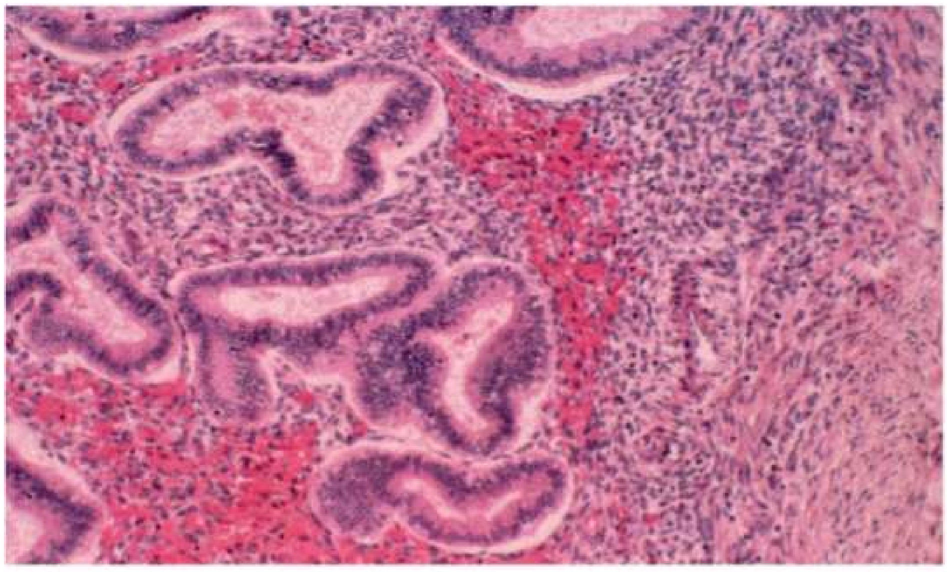
One of the more established ideas to explain what causes endometriosis suggests that these rogue cells are the product of "retrograde menstruation". The idea is that some menstrual blood ends up being returned into the body, taking these uterine cells with it and enabling them to implant in the wrong place.

But this idea doesn't explain all cases of endometriosis, says Katie Leap at the University of California, Los Angeles. "You can find endometriosis in fetuses, in men and in girls who haven't menstruated," she says.

To learn more about the problematic patches of cells, known as lesions, Leap and her colleagues compared them with typical cells found in the uterus lining. Specifically, they looked at the cells' epigenetic age: their biological age based on the presence or absence of chemicals that switch genes on or off.

The researchers analysed tissue samples collected from 60 women, 35 of whom had endometriosis. They found that the biological ages of the tissues were different. While uterus cells had an age similar to the women's chronological age, the cells from endometriosis lesions were around 16 years younger on average (bioRxiv, doi.org/dg99).

Endometrial tissue (dark purple) inside an ovary



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The biological ages of these lesions were actually more like those of teratomas: tumours formed of multiple cell types, sometimes including hair and teeth, which can form during embryo development.

The researchers say this suggests some endometriosis lesions may also appear this early. As an embryo develops, cells that eventually form the uterus must move into the correct position. But "it's possible that some tissue gets left behind", says Leap. "That's what happens with teratomas."

This doesn't mean that retrograde menstruation doesn't happen, but Leap says it is unlikely to be the only cause of the different subtypes of endometriosis. The finding may improve diagnosis and treatment.

This evidence is suggestive, but not yet strong enough to confirm the idea, says Caroline Gargett at Monash University in Melbourne, Australia. The idea that endometriosis lesions are present at birth is "still a theory waiting to be proven with more detailed studies", she says. ▮

Chemistry

Police could identify illegal drugs with magnetic levitation

A DEVICE that uses a form of magnetic levitation to separate components of illegal drugs could be useful in the fight against crime.

Street drugs are often a mixture of substances, and police forces need to be able to identify exactly what they contain in order to enforce the law.

The new approach to this problem, devised by Christoffer Abrahamsson at Harvard University and his colleagues along with the US Drug Enforcement Administration, involves adding a drug sample to a magnetic liquid and placing this mixture in a container with magnets at its top and bottom.

The thermos flask-sized device, which only costs around $200 to build, separates components of the sample by their respective densities. The magnetic liquid attempts to push particles of drugs away from the magnets in order to minimise the energy of the system, while gravity and buoyancy also act on them.

The overall effect is that drugs with the same density as the liquid will stay in the middle of the container, while those of higher density will sink and those of lower density will rise.

These density readings can then be matched to a reference value for pure substances such as heroin or MDMA (*Angewandte Chemie*, doi.org/dg8s).

New synthetic drugs can also be spotted more quickly because they will have densities that can't be matched to reference values. Further chemical analysis could be used to figure out what they are.

"Street drugs are often a mixture of substances, and police need to be able to identify what they are"

Ruth Morgan at University College London says the device could prove useful to law enforcement.

"Being able to achieve a separation of distinct substances sounds very promising and certainly applicable to the challenge of detecting specific substances that may be present within a mixed source sample that occurs in investigations," she says. ▮

Jason Arunn Murugesu

Medicine

Treatment for lupus targets overactive immune response

Ruby Prosser Scully

PROMISING results from an experimental treatment for lupus could lead to only the second new drug for the autoimmune condition in 60 years.

About 5 million people around the world are affected by lupus, a condition that causes the body's immune system to attack healthy organs and results in skin rashes, joint and muscle pain, fatigue and early death. There is no cure, and doctors often rely on treatments from the 1950s, says Eric Morand of Monash University in Australia.

A growing body of evidence suggests that lupus is linked to producing too many molecules called type 1 interferons, which help regulate the body's immune system. This prompted Morand and his team to study the effects of anifrolumab, a drug that binds to type 1 interferon receptors and stops the molecule from overstimulating the immune system.

The researchers gave 362 people with lupus 300 milligrams of a placebo or anifrolumab every four weeks for almost a year.

The benchmark for success was if all of a participant's organs that displayed signs of the disease at the beginning of the study improved and there were no flare-ups over the year. The team found that 48 per cent of people taking anifrolumab achieved this, compared with 32 per cent on the placebo (*New England Journal of Medicine*, doi.org/dg8p).

Sean O'Neill at the University of Sydney in Australia says the findings are a "great achievement for a disease that desperately needs some progress".

However, there are still negative side effects of anifrolumab to overcome. The drug was associated with an increase in upper respiratory tract infections, such as the common cold, and herpes zoster, also known as shingles. ▮

Cybersecurity

Scheme lets cops crack your phone, at a cost

Chris Baraniuk

IT'S the argument that just won't go away. For decades, governments have been lobbying for encryption "backdoors": ways of accessing people's private messages should law enforcement agencies want a peek. It will help them catch terrorists, they insist. But computer scientists have always pushed back. Weakening encryption damages everyone's security, they say.

Now, Sacha Servan-Schreiber at the Massachusetts Institute of Technology and Archer Wheeler at Brown University in Rhode Island have proposed a potential compromise: backdoors with steps that would make them costly for law enforcement agencies to exploit, rendering mass surveillance unlikely.

"We hope to show that a middle ground is feasible and to provide a counter argument to the reasoning that *carte blanche* government backdoors are necessary," they write in their paper (arxiv.org/abs/1912.05620).

In essence, the scheme adds multiple steps to the process of accessing a locked phone or social media account. For example, if police want to unlock a suspect's smartphone, they first have to request access from "custodians": servers owned by the government or academic institutions.

Should these organisations verify a request as legally sound, they would then allow the police to progress to the next step.

$900k

The amount the FBI paid to unlock a suspect's iPhone

The custodian servers would reveal the locations of multiple, randomly selected devices scattered around the country. Details of these would have been chosen by the target phone when it was first set up, and securely stored on the device.

Officers would have to physically go to each of these devices and scan them to obtain a digital signature, then present the signatures to the target phone. If they match the details stored on the phone, it would unlock itself.

Servan-Schreiber and Wheeler were inspired by the legal concept of a jury of peers, although they point out that the owners of these randomly selected devices wouldn't be asked to judge the lawfulness of the request and would have no say in the decryption process. The police would simply knock on their door, scan their smartphone and then leave.

"I thought it was a very interesting paper," says Steven Murdoch at University College London. However, flaws with the idea remain, he argues.

"What this scheme does is say, 'Surveillance is OK provided that it costs enough'. The problem with that is that's really the existing situation."

Following the 2015 San Bernardino shooting in California, the FBI demanded that Apple provide a backdoor to an iPhone used by one of the perpetrators. The tech giant declined but the FBI broke into the phone anyway with the help of cybersecurity experts who charged them $900,000.

Some think the researchers' proposal is a non-starter. "There is no ethical trade-off possible," says Erica Portnoy at the Electronic Frontier Foundation. "It's not ethical if it makes everyone less secure."

Murdoch says the debate over backdoors is endless. Law enforcement will always ask for more access and a society that has checks and balances should always push back, he says.

"I don't think this discussion is going to go away any time soon – and that's OK," he says. ▮

JANSOS/ALAMY STOCK PHOTO

Should police be able to access your private messages?

Health

Light therapy helps improve dementia symptoms

Linda Geddes

DAYTIME exposure to bright light seems to help improve sleep and relieve some symptoms of dementia.

As we age, our eyes' lenses grow cloudier, so less light reaches cells in the retina that connect to the brain's master clock. It is even worse for older care home residents who rarely venture outside, and who are often exposed to light at night to help keep them safe.

They can experience insomnia and disrupted circadian rhythms, which may present as excessive daytime sleepiness, nocturnal wandering and sundowning: agitation and irritability during late afternoon and early evening.

Since many care home residents with dementia spend their daytimes seated in communal areas, Mariana Figueiro at the Lighting Research Center, New York, and her colleagues designed a light table that directs light upwards. These were installed in eight US care homes, along with light boxes and floor lamps, to deliver light bright and blue enough to activate the circadian system.

The tables were used during daytime hours by 46 residents with moderate to late-stage dementia for four weeks. In another four-week period, they used a table with dimmer lights in a more yellow hue.

"The lighting reduced depressive symptoms and agitation, and improved sleep quality"

The bluer lighting significantly improved sleep quality, and reduced depressive symptoms and agitation, as assessed by the residents' caregivers (*Journal of Clinical Sleep Medicine*, doi.org/dg8v).

"They also told us that they were eating better and they were more social," says Figueiro. She suggests this means they are getting better sleep, which affects agitation and mood. ▮

Evolution

Tropical waters are an evolutionary hotbed

Michael Marshall

IMAGEBROKER/ALAMY STOCK PHOTO

Trilobites dominated the first great wave of marine life

THE tropics are the most biodiverse regions on Earth. Now there is evidence that they are also the main source of evolutionary innovation and diversity.

Complex animals have dominated Earth for 541 million years, a time span called the Phanerozoic eon. Huge numbers of species have evolved and gone extinct during this time, in a complex story that includes fish, giant reptiles and whales.

However, in the 1980s palaeontologist John Sepkoski analysed the overall pattern of evolution in the sea, where the fossil record is best. He concluded that marine evolutionary history could be broken down into three supergroups, which he called "great evolutionary faunas".

The first group was dominated by trilobites, which resembled woodlice, and bristle worms; the second by shellfish-like creatures called brachiopods; and the third by molluscs, which have persisted to the present day. Other animals like land mammals probably followed similar patterns, but their fossil record isn't complete enough for us to know.

Now, by analysing nearly 18,300 marine genera from the Phanerozoic fossil record, Alexis Rojas-Briceno of Umeå University in Sweden and his colleagues have found that the evolution of complex marine life is best described using four great groups of fauna, not three (bioRxiv, doi.org/dg98).

The first supergroup existed between 541 and 494 million years ago, spanning the Cambrian explosion in which many animal groups first emerged. As in the original analysis, trilobites dominated.

The second supergroup, dubbed the Palaeozoic, lasted from 494 to 252 million years ago. Creatures with hard outer shells were now widespread, including brachiopods. This phase ended when the end-Permian extinction wiped out almost all complex life on Earth.

This matches Sepkoski's analysis, but the new study splits his third great fauna into two. In this version, the third supergroup is called the Mesozoic. It began in the wake of the Permian extinction and ended 129 million years ago, in the middle of the dinosaur era. This time cephalopods, the group that includes squid and octopuses, were the rulers.

The fourth and final supergroup, the Cenozoic, is still dominant today. During this time, clams and snails have made up much of the diversity.

The team found that all four supergroups originated in the tropics, then expanded through the oceans. This is in line with the idea that the tropics are hotbeds of evolutionary innovation, which has been promoted by David Jablonski at the University of Chicago.

It may be that the warmer temperatures and ample sunlight ensure there is plenty of food to nourish a multitude of species. However, John Alroy at Macquarie University in Australia isn't convinced. "I have always been sceptical about the out-of-the-tropics hypothesis, because they have never seriously dealt with sampling biases, as far as I know," he says.

For Alroy, the problem is that more fossils are known from North America, Europe and Asia, whereas we have few from South America and Africa. "That's the fundamental problem with this kind of analysis, the concentration of data in a part of the world that has moved significantly," he says. ▮

Stem cells

Preventing organ rejection

Man with a donor kidney needs no anti-rejection drugs after injection of special cells

Clare Wilson

A ONE-OFF injection of cells could be a long-sought solution to the problem of the body rejecting an organ transplant.

The first person who may have benefited from this approach is an Italian man who had a kidney transplant. He has been completely tolerating his new organ for 19 months without anti-rejection medicines.

Transplants can be life-saving, but to stop the donor organ being rejected by the recipient's immune system, people have to take several drugs that have serious side effects, including cancer and infections – and they don't always work. The new treatment involves injecting mesenchymal stromal cells. This can be done the day before the transplant and seems to damp down the recipient's immune reaction in a way that "teaches" the body to accept the different tissues.

This type of cell can come from a variety of sources. Giuseppe Remuzzi at the Mario Negri Institute for Pharmacological Research in Milan and his team took them from the recipient's bone marrow, multiplied them in the lab, and reinjected them. After two years, blood tests suggested he was tolerating his new kidney so his anti-rejection medicines were gradually reduced over about five years and then stopped.

But it isn't clear if the cells were definitely responsible; in a second person given the treatment, blood tests didn't show tolerance. A few previous kidney recipients have developed tolerance to their new organ spontaneously – so perhaps the Italian man's response was another of these rare cases, says Emily Thompson at Newcastle University in the UK, who wasn't involved in the work. If the cells really were responsible, she says "it would be a pretty big deal".

Although the success of the treatment in the first case is unproven, studies by other groups suggest these kinds of cells can promote at least some level of tolerance. When six Dutch kidney transplant recipients showing initial signs of rejection were injected with the cells twice as an emergency treatment, they later showed signs of improved donor organ tolerance in blood tests.

Organ recipients usually have to take drugs for the rest of their lives

PHANIE/ALAMY STOCK PHOTO

The team behind the Dutch result has carried out a 10-person study using a post-transplant treatment with mesenchymal stromal cells from healthy donors. These have the advantage that they can be prepared in advance. The results aren't yet published, but are promising, says Marlies Reinders at Leiden University Medical Center in the Netherlands. She believes that these cells aren't powerful enough to let most people stop all their anti-rejection medication, but they should allow some reduction. "There would be less side effects," she says.

A trial in China that used mesenchymal stromal cells instead of other kinds of anti-rejection drugs found they led to fewer episodes of rejection in 156 recipients of kidneys.

The cells may not have to be generated anew each time they are needed. US biotech firm Athersys is developing an off-the-shelf therapy using cells called MAPCs, thought to have similar immune-suppressing effects. Thompson's team is trying a different approach of applying these cells to kidneys kept alive outside the body. ■

Environment

Oil spills could be cleaned by bacteria with extra genes

WE COULD help bacteria tackle oil spills by giving them enzymes that break down hydrocarbons, which would be more eco-friendly than alternative clean-up treatments.

Some microbes naturally possess enzymes that can break down the hydrocarbons that make up oil, but they are seldom found near spills. Katherine French at the University of California, Berkeley, and her colleagues want to give local bacteria the genes to make such enzymes themselves.

In addition to their main genome, almost all bacteria also carry extra pieces of DNA called plasmids that can be passed on to other species of bacteria. The researchers created a plasmid with genes for five enzymes involved in breaking down hydrocarbons, then added it to a strain of *E. coli*.

When the *E. coli* were added to polluted soil from an oil refinery, they all died within five days, but the plasmid was passed on to more than a dozen different wild bacteria species, which then began breaking down the oil (bioRxiv, doi.org/dg8n).

The amount of hydrocarbons in the soil fell by almost half in 60 days. Levels in samples to which the plasmid wasn't added fell by less than 5 per cent.

"Some microbes naturally possess enzymes that can break down the hydrocarbons in oil"

French thinks adding genes to local microbes could be more effective than engineering new ones to do the job, as these might not cope in a new environment.

Using microbes that naturally possess the enzymes is better than using chemical treatments, says Stephen Hawkins at the University of Southampton in the UK. "But I would be very, very wary about releasing genetically modified organisms into the environment." ■

Michael Le Page

Palaeontology

Fossil trees are remains of world's oldest forest

Jason Arunn Murugesu

THE remnants of the oldest known forest have been identified in a New York quarry. The fossils are about 386 million years old, and studying them could teach us more about how Earth's climate has changed.

Charles Ver Straeten at the New York State Museum discovered the fossils near Cairo in the Catskill region of New York. "Charles was just walking across the floor of the quarry and he noticed these big root structures, which are very distinctive," says Christopher Berry at Cardiff University, UK.

Three types of trees were found in the forest. One of them, of the *Archaeopteris* genus, had roots up to 11 metres long (*Current Biology*, doi.org/dg8z). These are similar to modern coniferous trees and were the first to have evolved flat green leaves.

New York is well stocked with old tree fossils because the state lies on an ancient mountain range. Natural erosion of the mountains by rainfall and glaciation shed the sediment that buried the trees and preserved them. The latest fossil find was just 40 kilometres away from what was previously considered the oldest forest in the world, beating the record by at least 2 million years.

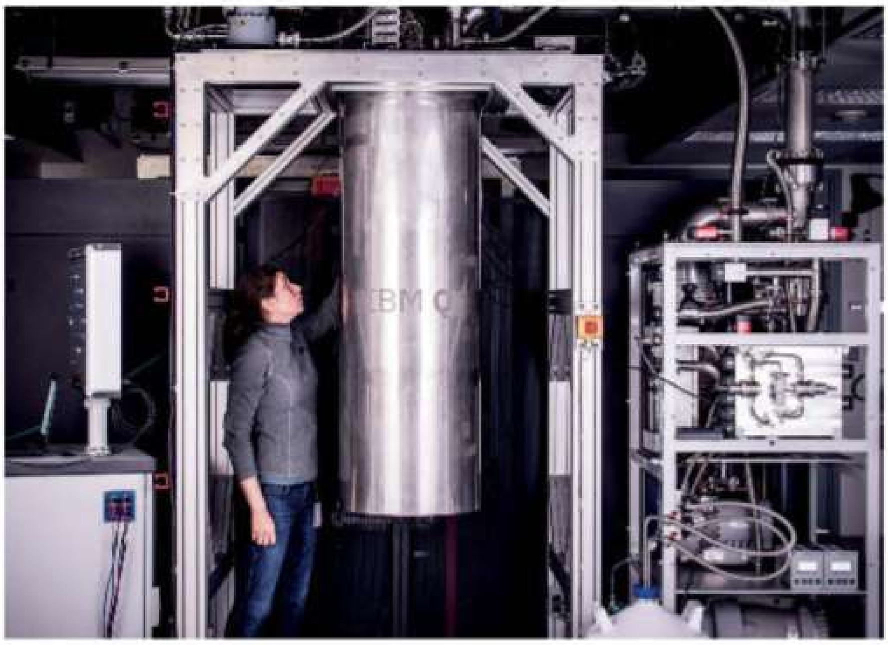
The plants played a role in the development of life on Earth, helping to cool the planet. "All these trees appearing was having an effect of removing carbon dioxide from the atmosphere," says Berry. "By the end of the Devonian period [360 million years ago], the amount of carbon dioxide was coming down to what we know it is today."

Studying the fossils could help us with modern climate change, says Sandy Hetherington at the University of Oxford. "Understanding how this happened in the past is crucial for predicting what will happen in the future in light of climate change and deforestation," she says. ▮

Conference report Q2B Practical Quantum Computing

All aboard the quantum bandwagon

Money is pouring in to developing quantum computers, but no one is quite sure what they are for, reports **Leah Crane**



IBM Q

A low temperature vessel housing a quantum chip at IBM

QUANTUM computing is booming, but is it a bubble? At a gathering of experts on this technology in California last month, nobody seemed to know how, or even if, it will turn out to be useful. The race for quantum supremacy may be over, but the race for a useful quantum computer is still on.

Quantum supremacy refers to the point at which a quantum computer can solve a problem that no classical computer could in a reasonable amount of time – a feat Google said it had achieved in October with an algorithm proving that strings of bits were random.

While that problem has no real practical value, it was a great demonstration that quantum computers can work. What most people are still waiting for is quantum advantage – the point at which these computers are better than classical computers for performing a useful task. A mix of researchers and investors in quantum computing gathered in December at the Q2B Practical Quantum Computing conference in San Jose, California, to discuss when and how that might happen.

The conference has more than doubled in size since its first event three years ago, now attracting more than 500 people. Announcements during the gathering of link-ups between quantum computing companies and firms like Ford and investment bank Goldman Sachs also point to rapidly growing interest in the field in the wider world.

But listening to the speakers, it wasn't clear what anyone expects from this boom. Many discussed how quantum computers are expected to be able to simulate molecules and chemistry better than classical machines, which could result in new materials and drugs. Others spoke of optimising stock portfolios and other big-data problems in the financial sector. Whether we will be able to build a quantum computer that is actually significantly better than a classical computer at doing any of that is still up in the air.

"If we aren't ready for the race, then when it begins we will have a hard time getting started"

That isn't deterring investors from jumping on the bandwagon though. "If you wait for *New Scientist* or someone to say we're now at quantum advantage before you start looking into quantum computing, it could take two years before you're ready to take advantage of it," says Bill Hartnett at investment bank Citi. "There's a sort of insurance aspect to it."

Oliver Wick, who leads BMW's quantum computer group, has a similar view. "It's like a 100-metre race. We have to get ready, because if we aren't ready for the race, then when it begins we will have a hard time getting started," he says. "I don't have a business case, it's just about readiness."

But researchers at Q2B also spoke about avoiding hype and the idea that quantum computing will solve every type of computing problem (see page 13). "Quantum computers are not general-purpose devices," said IBM's Katie Pizzolato. "They will always be best when they are applied to the right problems."

For now, though, it isn't clear what the right problems will be. "It may be that we'll find useful applications, but we can't guarantee it," said John Preskill at the California Institute of Technology. "I think we have reason to be optimistic about quantum technology having a transformative effect on society eventually, but that may take decades of hard work and investment."

How long it takes will depend on whether the current appetite for funding quantum computing holds up. "There is a real risk of running out of goodwill and funding in the mean time," said Google's Ryan Babbush. If that happens, we may never learn what quantum computing is really good for. ▮

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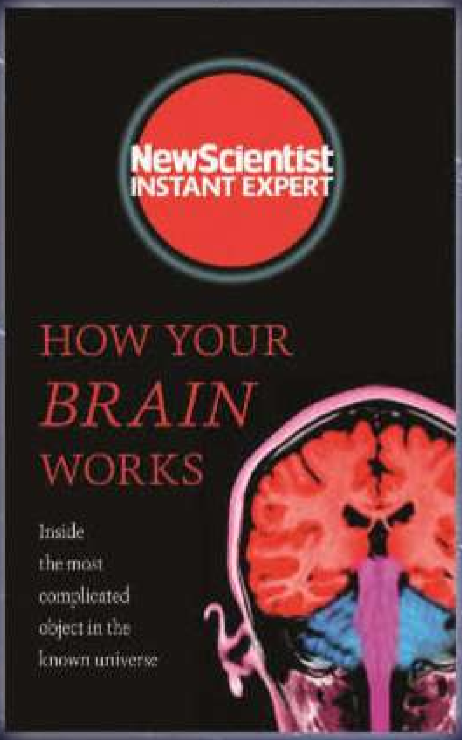
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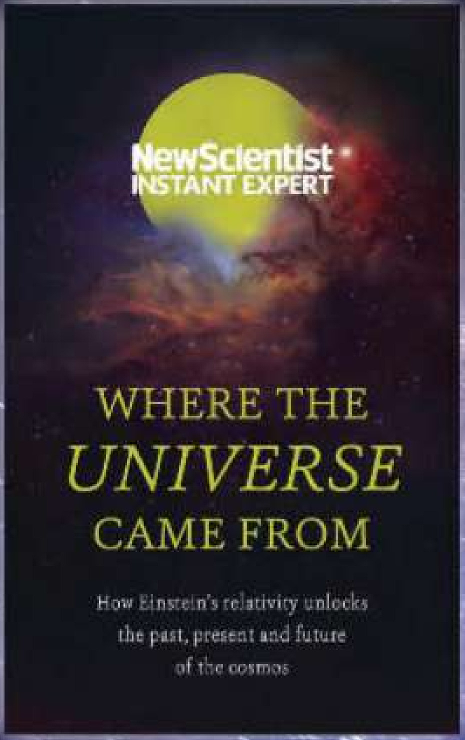
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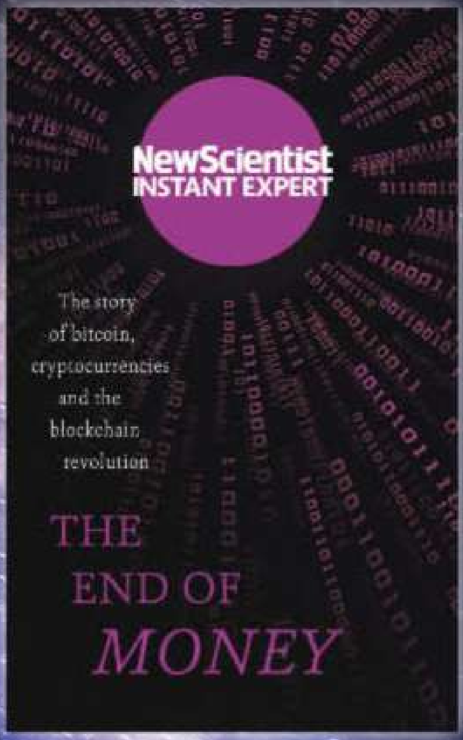
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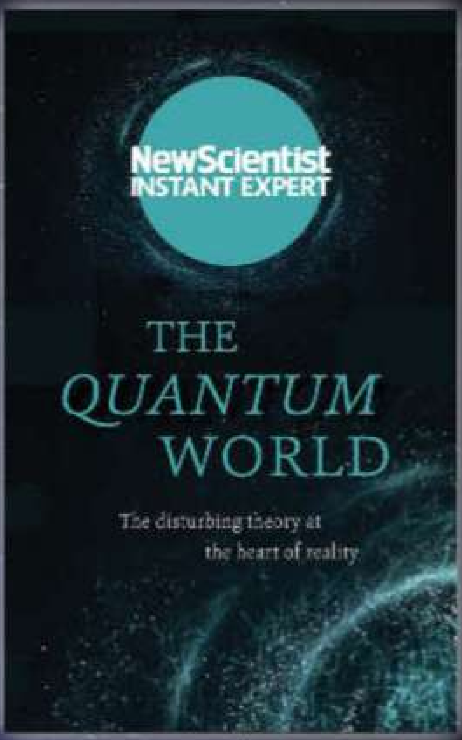
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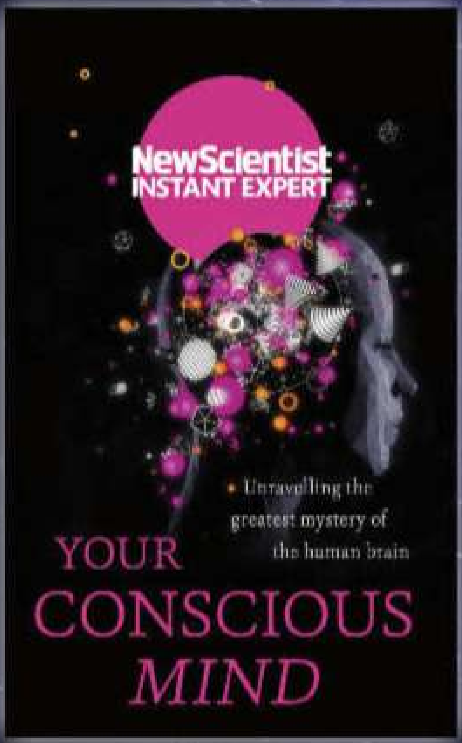
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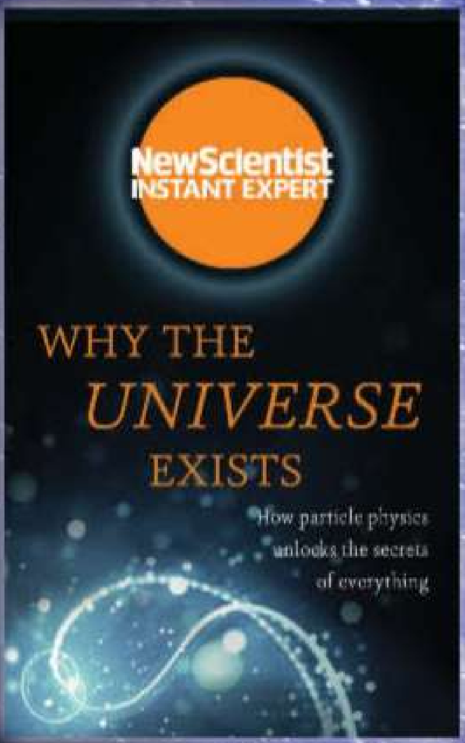
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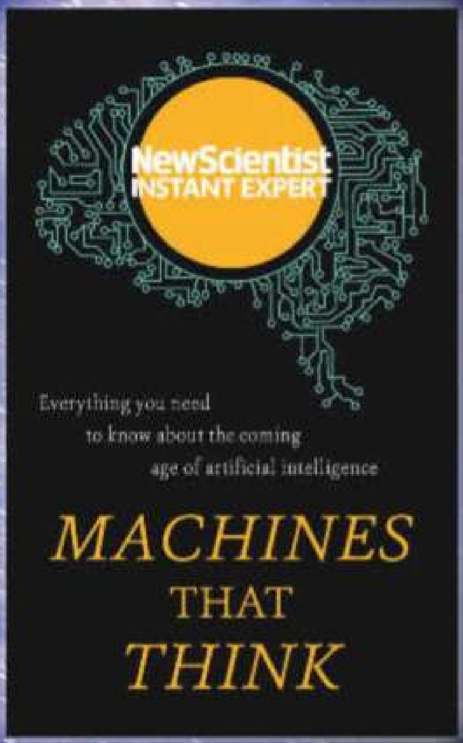
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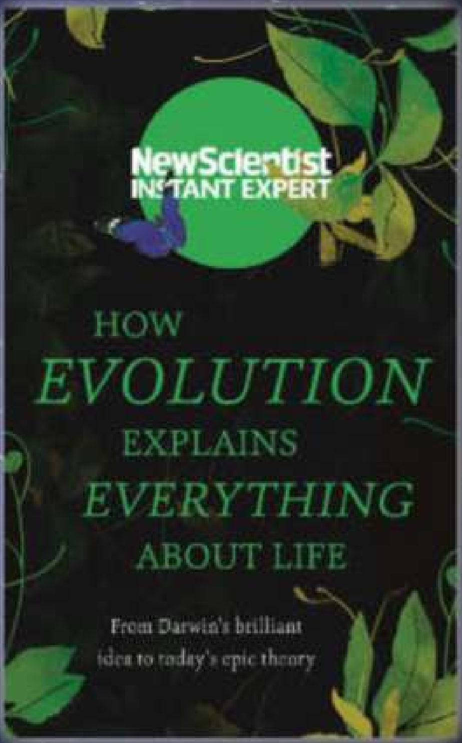
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Health

Nerves at risk from genital surgery

An increasing understanding of clitoral anatomy could prevent harm to patients

Ruby Prosser Scully

COSMETIC genital surgery is increasingly popular, but new research suggests crucial nerves are at greater risk of injury during vulval surgery than many surgeons may realise.

Textbooks rarely depict or describe the dorsal nerves going to the clitoris, and the organ is often depicted as smaller than it is, says Paul Pin at the Baylor University Medical Center in Dallas, Texas.

Basic anatomical research on the clitoris has lagged behind that of the penis, he says. To address this, he and his colleagues dissected the clitoral regions of 10 cadavers of women aged 43 to 88.

They found that the nerves responsible for sensation and orgasm ranged from 2 to 3 millimetres in diameter, similar in size to the nerves running along the shaft of the penis and in the index finger (*Aesthetic Surgery Journal*, doi.org/dg72).

These nerves sit millimetres under the surface of the clitoral hood, the fold of skin that protects the pea-sized glans.

Similar measurements were found in a study of 27 cadavers led by Marlene Corton at the University of Texas Southwestern Medical Center (*American Journal of Obstetrics and Gynecology*, doi.org/dg7z).

These studies are the first to thoroughly measure the size of the clitoral dorsal nerves, and they change the conventional understanding that these nerves are small and situated deep below the surface.

Labiaplasties are cosmetic surgeries designed to reduce the size of the fleshy lips of the vulva, though surgeons sometimes also reduce the size of the clitoral hood.

Pin worries that a lack of information on clitoral anatomy means many surgeons performing labiaplasties don't realise the nerves are even there. "But they are large, superficial and therefore very susceptible to injury if you don't know what you're doing," he says.

This is concerning in light of the growing popularity of labiaplasties. Between 2003 and 2013, Australia saw a threefold rise in the procedure, and the UK experienced a fivefold increase. In the US, there was a nearly 500 per cent increase in the surgery between 2011 and 2018.

> "Women have been harmed in all sorts of ways by surgeons who didn't know any better"

Pin collaborated on this work with his daughter Jessica Pin, who is also at Baylor. She had a labiaplasty and claims that the dorsal nerves of her clitoris were cut during the procedure.

"In the years following my surgery, I was repeatedly told my loss of clitoral sensation couldn't have happened," she says. "I was told by the [doctors] I turned to that I just needed to relax, just needed to fall in love."

Michael Goodman at California Northstate University says internet forums are full of stories of botched labiaplasties. "There are all sorts of ways women have been harmed by well-meaning surgeons who didn't know any better," he says.

Goodman adds that well-trained plastic surgeons or gynaecologists can safely perform the procedure.

Gino Pecoraro at the Royal Australian and New Zealand College of Obstetricians and Gynaecologists says these findings show how important it is to avoid unnecessary surgeries in this area. He says a true medical need is rare, and a more detailed understanding shouldn't be seen as a green light to perform them.

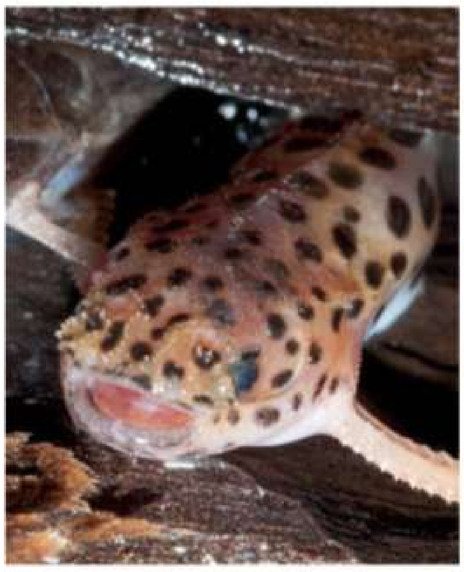
Zoology

Weird jaguar catfish is covered in spines and lives in logs

THE murky waterways of the Amazon rainforest often produce species previously unknown to science. But some are weirder than others. The newest oddball is a catfish that has spines, lives in a log and has a jaguar's spots.

The catfish was probably already circulating in the freshwater aquarium trade for years, but it hadn't yet been scientifically classified.

Marcelo Rocha at the Amazonas State University in Brazil and his colleagues first gathered the catfish on an expedition nearly a decade ago, and now the preserved specimens have finally received an official description, verifying the fish as a new species



MARCELO ROCHA ET AL.

The moijiri catfish is found in rivers in Peru and Brazil

The team found the fish in the Juruá river in Brazil and Nanay river in Peru, squeezed within the crevices of submerged logs. It is a type of driftwood catfish, a family of South American catfishes that spend their days wedged into tight spaces in wood and rocks, only emerging at night to feed (*Fish Biology*, doi.org/dg8h).

The new species is thumb-shaped, with the stumpy face of a salamander and skin patterned with jaguar-like rosettes. Prickles adorn its head, and its dorsal and two front fins have saw-like serrations.

The team named the fish *Spinipterus moijiri*. The fish is called the *moijiri* in Paumari, an indigenous language in Brazil.

The *moijiri* is a remarkable discovery because, until now, there was only one other catfish quite like it, says Bárbara Calegari, a driftwood catfish specialist at the PUCRS Museum of Science and Technology in Porto Alegre, Brazil.

Calegari says that the *moijiri*'s size is a surprise. It is 10 centimetres long, roughly four times the size of the only other known member of the *Spinipterus* genus. Several other driftwood catfish have jaguar-like spots but aren't closely related, which suggests the pattern evolved independently, says Calegari.

Reports of other, similar fish in the aquarium trade across South America show that there are probably many more species of driftwood catfishes waiting to be revealed, says Calegari.

Jake Buehler

Physics

Tiny bits of graphene help reveal secrets of ice formation

Leah Crane

WHEN a droplet of water freezes, it usually starts with a tiny particle on which the first ice crystals form before they spread through the rest of the water. Now we know exactly how big a particle needs to be to start the process, potentially paving the way to new forms of antifreeze.

Water doesn't always turn to ice at the same temperature. "A bottle of very pure water remains liquid even below 0°C," says Xin Zhou at the University of the Chinese Academy of Sciences in Beijing. To freeze, water requires ice nuclei to be present. Most commonly, these are small particles of impurities.

To see how particle size affects this process, Zhou and his team used trillions of flecks of graphene oxide. They mixed water with a given size of tiny sheets of the material, from 3 square nanometres to 50 square nanometres, and then lowered the temperature.

When they used flecks smaller than 8 square nanometres, the ice nucleation effect was weak, with ice only forming on the edges of the nanosheets at around -27.5°C. But at 8 square nanometres, nucleation was much more notable and the critical temperature where ice starts to form jumped up by about 10°C (*Nature*, doi.org/dg73).

They concluded that a particle must be about 8 square nanometres or bigger to act as an ice nucleus at these temperatures. They also confirmed that the process was the same with other nanoparticles.

The effect works in reverse, too. When they tested a coating of particles smaller than 8 square nanometres applied to a surface, it impeded ice formation, so a similar material could be used on anything you don't want to get icy, says Zhou.

He hopes that this knowledge will allow us to design better antifreeze coatings, for example for aircraft to prevent a dangerous ice build-up. ▮

Technology

Huge optical computer could outpace quantum computing

Edd Gent

A MACHINE being built from a 5-kilometre-long fibre-optic cable coiled into a box a few metres across could give quantum computers a run for their money on certain tasks. The device, which will perform calculations using pulses of light, will be one of the most sophisticated optical computers ever made.

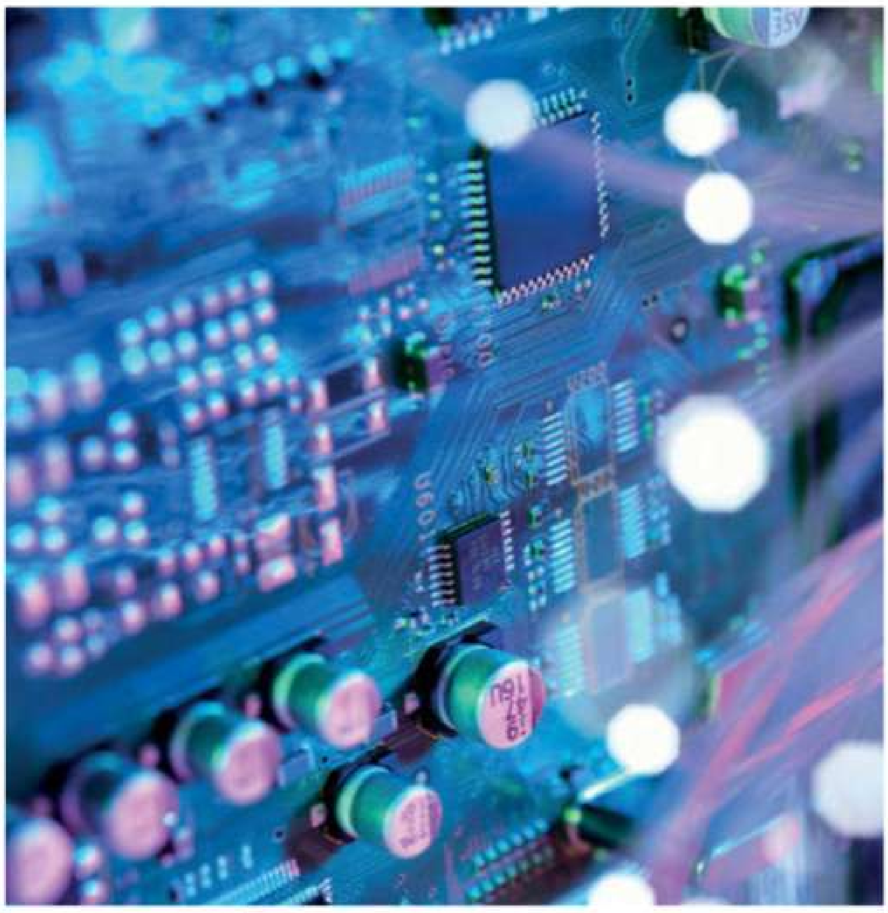
The computer, which is being built by Hiroyuki Tamura and colleagues at Japanese tech firm NTT, is designed to solve optimisation problems. These involve finding the best solution out of many possible ones, such as the best way to balance an energy grid or the most efficient way to schedule deliveries around a city.

Rather than relying on electrical circuits, the device will shoot 100,000 optical pulses into the coil, where they will follow each other round in a procession. Optimisation problems typically involve complex interconnected networks, so a special computer chip will encode the characteristics of this network into the pulses as they fly past. The pulses circulate around the coil tens or hundreds of times, interacting with each other until they find a stable state representing the best solution.

100,000

Number of pulses of light the computer can control at once

The team has previously built a version that could squeeze 2000 pulses into a 1-kilometre-long fibre. The new version will fit 100,000 pulses into 5 kilometres of fibre. That will allow the computer to model problems with up to 100,000 moving parts, such as the layout of real-world communication networks.


CULTURA CREATIVE (RF) / ALAMY STOCK PHOTO

"This would definitely be quite groundbreaking," says Charles Roques-Carmes, who studies optical computing at the Massachusetts Institute of Technology. At that scale, conventional computers would take centuries to find exact solutions and even programs designed to find approximate solutions to real-world problems would be slow, he says.

Optimisation problems are challenging for conventional computers because the number of possible solutions rises exponentially as the problem grows, requiring ever more computing power. Quantum computers have a natural advantage over conventional computers on these problems, but the technology is still in its infancy (see page 10).

In a paper published last year, NTT's computer containing a 1-kilometre-long fibre was tested against the D-Wave 2000Q, the first commercial quantum computer, on a series of experimental optimisation problems. While the D-Wave did better at small problems, NTT's device did significantly better on bigger problems with many interconnections, which are more indicative of real-world problems.

Will optical computers ever see the light of day?

More powerful and broadly applicable quantum computers being developed by companies like Google and IBM may ultimately outperform the optical computer, says Tamura, but it will probably be decades until they are large enough. The 100,000 pulse machine should be ready within a year or two, he says. ▮

Anatomy

Wearing shoes can weaken ankle bones

Michael Marshall

PHOTOALTO/SIGRID OLSSON/GETTY IMAGES

YOUR shoes are changing your feet. The ankles of people who habitually wear shoes are different to those of people who tend to walk barefoot.

In many industrial societies, people tend to wear shoes from a young age. However, many people around the world often go barefoot, or wear only very thin footwear.

"We know that there are some variations in the feet of modern humans, due to the use of shoes," says Rita Sorrentino at the University of Bologna in Italy. But most previous findings relate to the front and middle of the foot. She and her team have focused on the ankle instead.

They studied 142 ankle bones from 11 populations from North America, Africa and Europe. These included sandal-wearing Nguni farmers in southern Africa, people living in New York and fossilised bones from Stone Age hunter-gatherers.

The hunter-gatherers' ankle bones were significantly shorter than those of people living in modern cities, and there were other differences in the shape. "They are mostly related to footwear-related behaviours and locomotor behaviours," says Sorrentino.

People who mostly walk barefoot have more flexible ankle bones

The hunter-gatherers walked barefoot for long distances every day over natural terrain. Their ankles were relatively flexible. In contrast, people who live in big cities, who wear constrictive footwear and walk short distances on flat surfaces like asphalt roads, had more rigid ankles (*American Journal of Physical Anthropology*, doi.org/dg75).

Changes to ankle bones take place over the course of a person's life, and there is no evidence that these alterations can be passed on genetically.

Solid evidence for people wearing shoes only exists for the past 10,000 years, says Sorrentino. For instance, a sandal from a Missouri cave may be 8300 years old. Early shoes were all fairly soft, such as moccasins or sandals, so wouldn't have restricted the motion of the ankle much.

It is an open question whether shoes have disadvantages, but Sorrentino suspects that the rigidity of modern shoes causes our bones to become weaker and more prone to fracturing. ▮

Genetic modification

Potatoes engineered to kill major pest

Michael Le Page

A PROBLEM with pesticides is that they also kill non-pests. Now biologists have engineered potatoes to be lethal to a major pest but harmless to other species, no pesticide required.

Ralph Bock of the Max Planck Institute of Molecular Plant Physiology in Germany has genetically modified potatoes to shut down an important gene in the Colorado potato beetle. "I'm quite optimistic that it will provide an additional weapon to deal with pest insects," he says.

The approach uses a method known as RNA interference, or gene sequencing. Introducing double-stranded RNA molecules into the guts of the beetles can trigger a cellular defence mechanism that destroys any similar single-stranded RNAs in the cell. This stops a crucial gene from being able to function, as single-stranded messenger RNA is the intermediary that enables DNA instructions to make the proteins they encode.

In most animals, including us, any RNAs in the gut or bloodstream are quickly destroyed. But insects have been found to absorb double-stranded RNAs from their guts, and feeding them these can be enough to trigger gene silencing in much of their bodies.

GETTY

The Colorado potato beetle has spread from the US to Europe

Trials by several groups have shown that spraying RNAs onto crops can protect them from pests while leaving some closely related insects unharmed. But producing the vast quantities of RNAs needed to do this would be extremely expensive, says Bock.

One solution is to genetically modify plants to produce pest-targeting RNAs themselves, rather than spraying these onto them. But this is tricky, because long bits of RNA are best for triggering gene silencing, and plant cells tend to chop these up into shorter pieces that don't work as well.

"I'm optimistic that this gene silencing will be a weapon to deal with these pest insects"

In 2015, Bock's team overcame this problem by making plants produce the RNAs inside chloroplasts, the cellular compartments used for photosynthesis. High levels of long RNAs can accumulate in the chloroplasts, which he has now found makes gene silencing far more effective in the beetles that eat the plant (bioRxiv, doi.org/dg8q).

The method is ready to transfer into any potato variety, says Bock, and a team in China is engineering the trait into commercial varieties for field trials. "We are testing the other properties of the potatoes, including yields and taste," says Jiang Zhang of Hubei University in China, who worked with Bock on testing the chloroplast method.

Antje Dietz-Pfeilstetter at the Institute for Biosafety in Plant Biotechnology in Germany doesn't think this chloroplast approach raises new safety issues. But crops should still be evaluated on a case-by-case basis, to confirm they don't harm non-target species, she says. ▮

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Conservation

There is no plan A

Efforts to save animals from extinction are fatally flawed because they fail to take climate change into account, says **Michael Le Page**

CLIMATE change is the greatest threat humanity faces – and we aren't the only ones at risk. Global warming will harm millions of other species, including iconic endangered animals such as polar bears and tigers. Despite this, conservationists often don't take climate change into account, meaning plans to preserve these species are doomed to fail.

"It's astonishing," says Miguel Araujo at the National Museum of Natural History of Spain. "I don't really understand the lack of action."

The outlook for wildlife would be grim even if the world wasn't warming. According to a major report last year, 1 million species could soon be wiped out – a sixth mass extinction. The main cause at present is the loss of habitat, but over this century the changing climate is expected to push ever more species over the brink.

A warming world poses numerous challenges to wildlife. For many plants and animals, their current habitats will simply get too hot. Lots are already moving to stay in their comfort zone. In the oceans, some organisms have shifted their ranges by hundreds of kilometres.

1m

The number of species that may be wiped out within a few decades

But on land there are few spaces left for animals to relocate to, and those that do exist are highly fragmented, which makes it very hard for wildlife to adapt, says Araujo. In polar regions, the loss of sea ice is posing problems for the polar bear and other animals.

At least one species has already been driven to extinction by climate change. Bramble Cay, a tiny, low-lying Australian island on the northern edge of the Great Barrier Reef, used to be home to a unique rodent called the Bramble Cay melomys. In 2016, a review found that the animals died out as rising sea levels led to the island being inundated during storms.

IMAGEBROKER/ALAMY STOCK PHOTO

Some Bengal tigers live in mangroves that may be hit by rising sea levels

There had been a recovery plan for the species – but it stated that climate change was unlikely to have a major effect, says Lesley Hughes of Macquarie University in Sydney. She describes the lack of conservation preparedness for climate change as lamentable.

Such a disaster may already have been repeated (see "Blown away", right), and will certainly happen again on low-lying coasts and islands. Animals at risk include Bengal tigers clinging on in the mangrove swamps of the Sundarbans in Bangladesh. By 2070, there might be no suitable habitats for the tigers left there.

It will be necessary to create new protected areas as the world warms and coasts flood, along with corridors that allow animals to move between such places. That is costly and isn't being done in rich places like Europe, let alone in poorer countries such as Bangladesh, says Araujo.

Even plans to save high-profile species often fail to take warming into account. For instance, millions have been spent on attempts to save the Iberian lynx. It is now increasing in numbers, but efforts have focused on the southern part of the Iberian peninsula where conditions will become too dry for the cats during this century.

Population crash

"It's inevitable that a population crash will happen unless they are able to move," says Araujo. The aim should be to reintroduce the cats in the north of the peninsula, where conditions will remain favourable, he says.

This is far from an isolated case. When Aimee Delach at conservation organisation Defenders of Wildlife, based in Washington DC, analysed official plans for saving 459 animals in the US that could soon go extinct, she found only 18 per cent of the strategies included actions specifically designed to compensate for climate change.

That is despite 60 per cent of the plans mentioning climate change as a threat. According to Delach's analysis, warming is actually a threat to 99 per cent of the species.

The picture is similar elsewhere. Hughes and her colleague Malin Hoeppner looked at the recovery plans for 100 threatened plants and animals in Australia. Just nine recommended any action to cope with a climate change-associated threat, despite climate change being regarded as a danger to 60 per cent of the species, they reported in 2018.

"Our results show a gulf between knowledge about climate change risk and recovery planning," they wrote.

Another study looked at approved plans for saving 24 threatened plants in Australia. Nathalie Butt at the University of Queensland and her colleagues found just 30 per cent included actions that are crucial for helping species cope with climate change, such as moving specimens to areas where the climate remains suitable.

What's more, the researchers also concluded that 20 per cent of a further 1200 plants they looked at were at high risk of going extinct because of climate change. There are no plans at all for saving most of these species.

Why are so many conservation plans so woefully inadequate on the climate front? "It's a classic case of the 'knowing-doing' gap," says Hughes. The reasons we may

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fail to act even when we know what needs to be done include a lack of resources, an inability to believe that things could get as bad as forecast, a reluctance to intervene and a focus on short-term threats such as invasive species, she says.

That said, there is also a limit to what can be done. In Queensland, for instance, many animals, including threatened lemuroid ringtail possums (once wrongly reported to already be extinct due to climate change), are moving to higher elevations to stay in the right climate zone. However, that process can't continue indefinitely, as mountains only go so high.

If the planet keeps warming, entire habitats could disappear along with all the species that rely on them. The outlook for most coral reefs is bleak, and there are fears the entire Amazon rainforest could perish.

So limiting further warming is vital. For example, a recent study of emperor penguins in Antarctica concluded that if emissions keep rising, the birds could die out not long after 2100. If warming were limited to 2°C, their numbers would fall by less than half.

Other types of interventions might be appropriate to save some species. In 2016, John Woinarski of the Threatened Species Recovery Hub at Australia's National Environmental Science Program looked at why the Bramble Cay melomys and two other species, the Christmas Island pipistrelle and Christmas Island forest skink, had recently been lost.

"If Earth keeps warming, entire habitats could disappear along with all species that rely on them"

One reason was the failure to establish a captive population as numbers fell. It might have been possible to release the animals on another island – an approach that has saved a bird called the Guam rail from extinction. Woinarski and his team have recommended such action for some threatened species. "Unfortunately, none of our recommendations have been enacted," says Woinarski. On the contrary, the Australian government is now reviewing its environmental law, with the aim of reducing "green tape", he says.

Biologists did finally go to Bramble Cay in 2014 to try to catch some melomys, but they found none. It seems all too likely that history will soon repeat itself. ▮

Blown away

It isn't just creeping, large-scale changes in climate that pose an extinction threat. There are so few of some species left that they may be wiped out by local, short-lived events fuelled by global warming.

Landslides killed the last remaining specimens of a Hawaiian tree called *Cyanea dolichopoda*. Climate change is cited as one of the major contributory factors, says Craig Hilton-Taylor at the International Union for Conservation of Nature.

Hurricane Dorian, one of the strongest Atlantic storms ever, may have wiped out several bird species. Only a few Bahama nuthatches were left on Grand Bahama before Dorian hit the island last September. Several other species, including the Abaco parrot, may also have been lost, says Diana Bell at the University of East Anglia in the UK.

In December, claims that the devastating wildfires in Australia, made more likely by hotter, drier conditions, threatened the survival of koalas made headlines around the world. However, this was misleading. While their numbers are declining, there are still around 300,000 koalas (pictured) in eastern Australia.

However, many species with smaller populations could be wiped out by a bad fire season, says Dale Nimmo of Charles Sturt University, Australia. In 2015, fires burned much of the Western Australia habitat of the critically endangered Gilbert's potoroo, one of the world's rarest mammals. The mallee emu-wren in southern Australia was killed off by fires, but has been reintroduced from captive-bred birds elsewhere.

VICKI SMITH/GETTY IMAGES

Working hypothesis

Sorting the week's supernovae from the absolute zeros

▲ Facebook

A ranking of the most popular apps of the decade reveals the top four – Facebook, Facebook Messenger, WhatsApp and Instagram – are all owned by, uh, Facebook.

▲ Exoplanets

More than 100 alien worlds have received official names chosen by the public. Before you ask, Planety McPlanetface didn't make the cut.

▲ Pigloos

Wild pigs in Canada burrow into the snow to stay warm, creating tunnels called pigloos. Our early nomination for 2020 word of the year.

▼ *Cats*

Andrew Lloyd Webber's fever dream has become a CGI movie horrorfest. A CRISPR-fuelled live show is the next logical step.

▼ Parthenon

The building in Greece is one of the most ancient in the world – but it turns out its name belonged to another structure entirely.

TOP: GRZEGORZ KNEC/ALAMY; JASON KNOTT/ALAMY

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Views

The columnist
Chanda Prescod-Weinstein on a dark mystery **p20**

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Can we be so certain that no computer can be conscious? **p22**

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The books, games, films and events on the way in 2020 **p24**

Aperture
The Byzantine beauty of a magnified surgical stitch **p28**

Comment

Spread the word on HIV drug

PrEP is an effective tool for eliminating HIV, but stigma and ignorance are hindering its uptake, says **Doug Johnson**

JOSIE FORD

IN 2016, the UN issued its "Political Declaration on Ending AIDS", aiming to rid the world of the HIV epidemic by 2030. One target for 2020 was to reduce new HIV infections to fewer than 500,000 by, among other things, reaching 3 million at-risk people with pre-exposure prophylaxis (PrEP) by this year. But this target is set to be missed by a country mile, hindering the global fight.

PrEP is a pill containing two chemicals, tenofovir and emtricitabine, that kills HIV before it can infect a person. It can be taken either daily, or at specific times prior to sex, and has been shown to help protect many groups particularly at risk of transmission, including sex workers, intravenous drug users and men who have sex with men.

PrEP is both highly effective and works where the use of condoms and other prevention methods may not, for example in cases of sexual assault or needle sharing. It also empowers women, particularly important in sub-Saharan Africa where over half of new adult infections are among women, rising to two-thirds of new infections in young people.

Yet PrEP uptake remains underwhelming. In 2018, only 380,000 people were on the medication worldwide. Half of them were in the US, and very few in areas with high HIV prevalence, for example in eastern and southern Africa. "It's very patchy," says Rosalind Coleman, a PrEP consultant with the Joint UN Programme on HIV/AIDS (UNAIDS). Although every person who regularly takes PrEP helps stem the spread of the virus, "it's nowhere near enough if we want PrEP to have an impact on the HIV epidemic", she says.

Last month, UNAIDS published a global survey of barriers to PrEP access. Of 69 countries reporting PrEP availability, only 13 said there was no barrier. For the rest, high cost and limited accessibility of treatment were the most frequently cited problems.

Stigmatisation of at-risk groups plays its part too. The survey revealed that in some countries possession of PrEP can even be used as evidence of sex work or other criminalised sexual activity. "The systems often actually screen out or exclude exactly the people who need PrEP," says Mitchell Warren of AVAC, an HIV prevention charity based in New York.

Combating prejudice against PrEP users will take time, as will overcoming the disinclination of some at-risk people to take it – because taking a daily pill doesn't fit with their lifestyle, for example, or they don't want a constant reminder that they are at risk.

Meanwhile, there is a more mundane barrier. There have been decades of campaigns about condom use and other safe sex practices to lower HIV rates, but PrEP is a newcomer struggling to catch up. Awareness of how it works, and who should take it, remains low. "PrEP got developed," says Warren. "Science showed that it worked, but most people in the world don't know it exists."

Where that barrier can be broken down, change can happen fast. In South Africa, a concerted education effort has seen the country recently exceed its target for PrEP uptake, with an estimated 35,000 people using it. Young people at higher risk of HIV infection were particularly eager, says Linda-Gail Bekker of the Desmond Tutu HIV Centre at the University of Cape Town, who helped run clinical trials on PrEP in South Africa. "Once people wrap their heads around it and they recognise that they are going to be able to be in charge of their own destiny, as it were – this is what we're really hearing from young women – they do get very excited," she says.

Easier, more convenient methods of using PrEP are also being developed, including a version that needs to be taken only monthly. But with just a decade left to meet the UN's goals, there is one thing above all that must be spread: awareness that PrEP exists, and that it works. ▮

Doug Johnson is a journalist based in Montreal, Canada

Field notes from space-time

Are dark matter and dark energy related?

There is no law of physics dictating that these phenomena can't be connected, and it is natural to wonder about it, writes **Chanda Prescod-Weinstein**

Chanda Prescod-Weinstein is an assistant professor of physics and astronomy, and a core faculty member in women's studies at the University of New Hampshire. Her research in theoretical physics focuses on cosmology, neutron stars and particles beyond the standard model

Chanda's week

What I'm reading

I'm currently working my way through Annette Gordon-Reed's The Hemingses of Monticello.

What I'm watching

I found the film Bait 3D *to be surprisingly compelling.*

What I'm working on

My editor just gave me feedback on a draft of my forthcoming book The Disordered Cosmos, *so I am plugging away at edits.*

This column appears monthly. Up next week: Graham Lawton

DARK matter and dark energy are mysterious phenomena that have captured the attention of astronomers, cosmologists and particle physicists for decades and they both have the word "dark" in them, so they must be related right?

After my last column, a curious reader wrote to me to ask about the relationship between the two phenomena. I have decided to use this first column of the year to answer this question, which goes to the heart of some of our most fundamental concepts in physics and some of our biggest open problems in astrophysics and cosmology.

Dark matter and dark energy are related, but perhaps not in the way you might expect. For the most part, theoretical physicists and observational astronomers expect them to be different entities, and the majority of our research is organised around the idea that they have very little relationship to one another. Mostly what connects them is a tendency of 20th-century scientists to name things they can't see or understand as "dark".

To understand the difference, you need a grasp of what matter and energy are. Most people probably encounter these physics concepts through pop culture representations of Albert Einstein's famous equation, $E = mc^2$. "E" represents energy, the "m" represents mass, and "c" represents the constant speed of light.

Mass is a measure of roughly how much matter there is. We are most intuitively familiar with mass via gravity: here on Earth, our mass determines the strength of our gravitational interaction with the planet, something more popularly known as our weight. We understand that our weight roughly gives a measure of how much matter there is inside us.

Energy is a more abstract concept and developing an intuition for it generally takes time, even for students of physics. We can get some feeling for it from Einstein's famous equation, which tells us that an object that has mass has an equivalent energy that is found by multiplying the mass by the speed of light squared.

Part of what makes Einstein's relativity so powerful is that this equation shows that the traditional Newtonian distinction between energy and matter is unnecessary. When we combine this idea with the revelations of quantum mechanics, we find that where there is matter, there is energy, and where there is energy, there is the potential for matter to randomly appear.

> **"Where there is matter, there is energy. Where there is energy, there is the potential for matter to appear"**

Because of this matter-energy equivalence, particle physicists tend to state measurements of both mass and energy in units of energy.

Relativity isn't the only theory of physics that informs our thinking here. In Einstein's theory, empty space isn't predicted to have any energy in it, but in quantum mechanics, empty space (also known as the vacuum) will have an energy associated with it.

It is here that we run into what is often called the "cosmological constant problem". Quantum calculations predict that there will be an energy everywhere in space-time, even when there is no matter present. But astrophysical observations tell a different story.

In 1998, the expansion of space-time was found to be accelerating with time and the simplest theoretical explanation for this is the presence of a cosmological constant, a vacuum energy that is everywhere.

Importantly, because of the matter-energy equivalence, vacuum energy has the potential to interact with gravity in a manner similar to that of massive objects, except instead of acting attractively, a vacuum energy with a positive value will act like a pressure pushing outward, forcing space-time apart.

The exciting discovery of cosmic acceleration has also created a mystery because the amount of vacuum energy needed to match the data is much smaller than the amount of vacuum energy predicted by quantum calculations. This is known as the dark energy problem.

This is quite different from the dark matter problem. As I explained in an earlier column, the dark matter problem is to do with missing mass in galaxies (15 May 2019, p 26).

We think dark matter manifests as a massive object, while dark energy doesn't. Yet there is no law of physics that says dark matter and dark energy can't be connected. Together they make up 96 per cent of the combined matter-energy in the universe, and it is natural to wonder whether they are related.

Over the years, physicists have considered this possibility, and along with two of my colleagues, I am now one of them. It is too early to say whether our model works. It may be that, in the end, the only connection between dark matter and dark energy is our ignorance about how they both work. ▮

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Editor's pick

Oh, to be so certain that no computer can be conscious

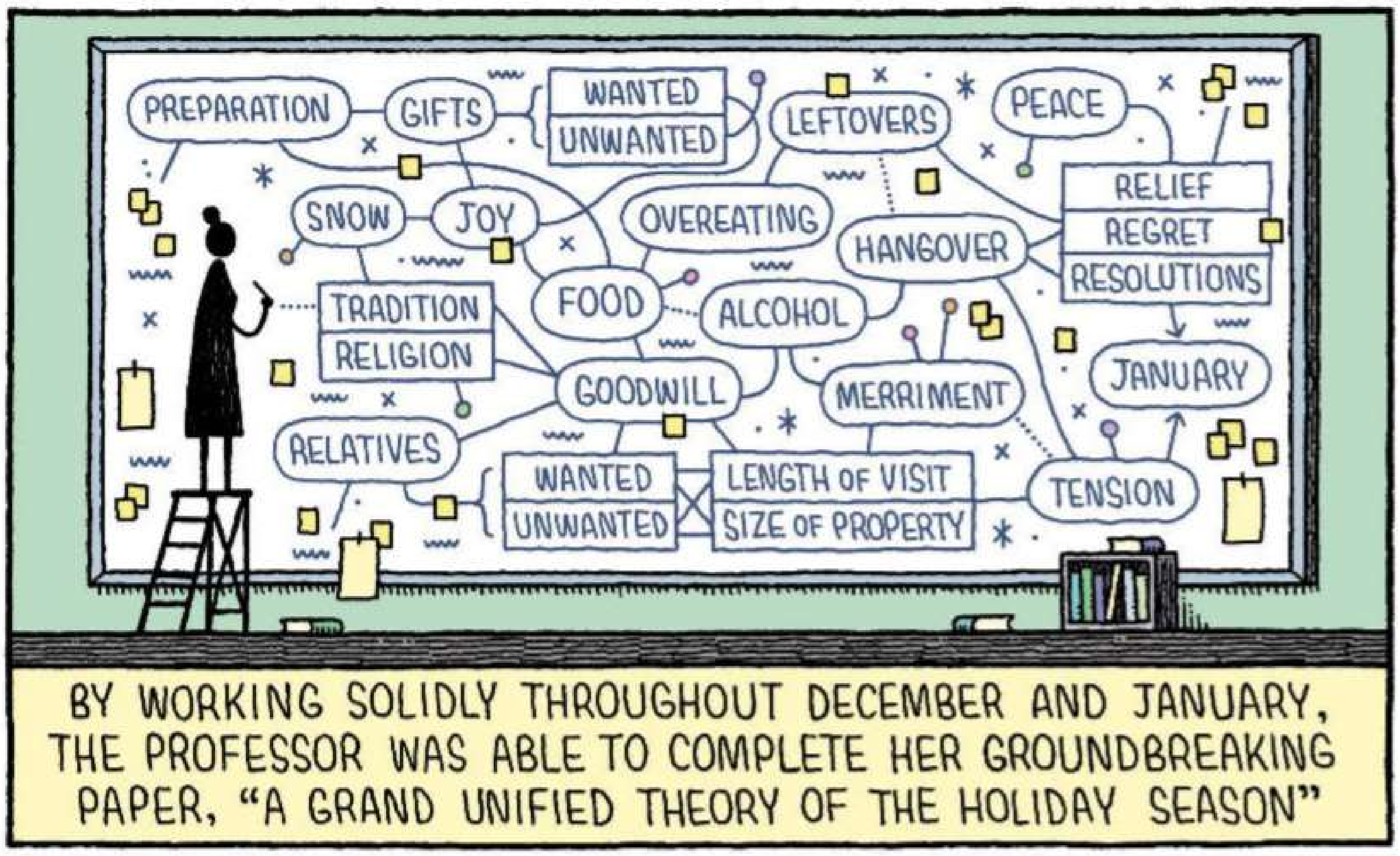
2 November 2019, p 28

From Sam Edge,
Ringwood, Hampshire, UK

Alun Anderson reviews *The Feeling of Life Itself* by Christof Koch and claims that computers can never be conscious. I recall you reporting Danko Nikolic saying that machines "cannot exceed human intelligence, ever" (26 March 2016, p 23). Before this, many others said that a computer would never beat all humans at chess or Go, translate a language or recognise human faces.

Yes, a general-purpose digital computer is deterministic, agentless and without self-causality. Yet it can be programmed to simulate anything, including non-deterministic, self-causal systems unlike itself.

It may be that simulating a system capable of exhibiting consciousness isn't computationally feasible for a Turing-type computer of any power. But the article's description of "animats" as evolving non-biological creatures used to investigate consciousness suggests the possibility of constructing something that is somewhat self-causal. This may be difficult, but we know the laws of nature don't preclude it because we experience consciousness ourselves and we are bound by those laws. The only way to rule out computers achieving consciousness is to fall back on a dualism between the mind and those laws – in which case, there is no point in discussion. Dualism, like any faith-based belief, isn't amenable to scientific enquiry.



TOM GAULD for NEW SCIENTIST

How to achieve low-carbon domestic energy supply

Letters, 30 November 2019

From Mark Barrett,
UCL Energy Institute, London, UK

Readers Karen Hinchley and Jeremy Hawkes discuss ways to make homes net-zero carbon emitters. Renewable electricity, or maybe nuclear energy, can power heat pumps, either in individual consumers' homes or as district heating suppliers. Heat pumps are already widely implemented technologies and provide near-zero-carbon heating and cooling, which will be increasingly needed as climate change progresses.

They emit less carbon per unit of heat delivered than biomethane, which is in limited supply in any case, or hydrogen from natural gas or from electrolysing water. Wind power has increased from 2 to 18 per cent of UK generation in just 10 years. In 2018, total renewable electricity generation, with continued falling costs, reached about 110 terawatt-hours. This is enough to power some 20 million domestic heat pumps. In cold weather, consumer heat pumps would produce about twice the energy they used as electricity, and district heating systems would generate three or four times as much.

So, even if homes still lack substantial insulation, the peak electric load for heating would be 100 gigawatts or less, with a few hours of storage. All near-zero-carbon options require investments in these technologies, and also in networks and storage. There is no free carbon-free lunch.

Solar panels are useful, not least for hot water

9 November 2019, p 18

From Paul Whiteley,
Bittaford, Devon, UK

You quote energy efficiency consultant Russell Smith, who says home solar panels aren't always the best way to cut carbon. I presume he is talking about solar photovoltaics. I have these and a solar hot water system on my roof. The latter has been the best purchase I ever made. Storing the water is simple and doesn't need expensive converter technology or limited-lifetime batteries.

As long as the system is kept clean, output doesn't diminish over time. Every part is easily recyclable. For six months of the year, we get free hot water for a family of four, and for the rest of the year, it is at reduced price.

From Patrick Davey, Dublin, Ireland

I was pleased to read your article on energy efficient homes, but sorry that it is dismissive of solar photovoltaic panels. A properly designed system would allow all power generated to be used in the house or returned to the grid. Conventional power station generation and distribution is only 30 per cent efficient, so local solar generation saves around 2.7 kilowatts' worth of carbon for every kilowatt used at home.

Here in Ireland, no newly built houses are allowed to install gas boilers. The only new systems allowed are heat exchange.

Trees are more important than a permanent solution

Letters, 7 December 2019

From Adrian Bowyer,
Foxham, Wiltshire, UK

Adam Osen says an average person in a developed country releases about 14 tonnes of carbon dioxide a year, and a tree absorbs 22 kilograms a year on average. That is true, but it doesn't follow that everyone needs to plant 680 trees a year, because trees aren't a permanent solution.

They are much more important than that: they are a stopgap. The point of planting trees is to absorb a lot of CO_2 over the next 100 years or so while they are growing and while we completely decarbonise every aspect of human activity.

This is the basis of the trillion trees initiatives. With a human population of nearly 8 billion, we need to plant only about 130 trees each. This is completely feasible.

Recently, Ethiopia – a country with a population of 100 million and fewer available resources than many more developed nations – planted more than 350 million trees in just 12 hours.

Why weren't these effects of measles seen sooner?

9 November 2019, p 15

From Kaye Butler, Highworth, Queensland, Australia

Debora MacKenzie reports that measles infection damages children's immunity to other diseases. When I had measles in the 1940s, it seemed very common for children to contract it again shortly afterwards.

It is interesting that present research suggests this may have really been an unrelated disease with similar symptoms.

From Hillary Judd, Exeter, Devon, UK

In the 1950s and early 60s, before immunisation against measles, there were typically epidemics of measles every two years, affecting up to half a million people, mainly children. The majority would have been immunised against polio, diphtheria, whooping cough and tetanus.

But I am not aware of any increase in the incidence of these infections in the years following measles epidemics.

I had measles in the 1961 epidemic. I recall tales about being able to have certain childhood diseases more than once, but this was attributed to the difficulty in distinguishing between different common diseases.

Could this actually have been a consequence of infection pre and post-measles? I find it surprising that the reported effect of measles on the immune system went unremarked for so long.

Let's deliver contraceptives to control feral cats

23 November 2019, p 12

From Celine Szoges Schwartz, Thornbury, Ontario, Canada

I understand Australia's need to cull its large feral cat population, which has caused tremendous environmental damage.

But little has been done to provide chemical neutering for unfortunate stray and feral cats. Could the Felixer trap spray a contraceptive gel on feral cats instead of a poison?

Quantum computing, due at a superposition of dates

2 November 2019, p 9

From Will Kemp, Wagait Beach, Northern Territory, Australia

Quantum computers with practical uses could be decades away, says Chelsea Whyte. Is it too early to predict that the first truly useful quantum computer will be powered by the first truly useful cold fusion generator?

For the record

- Our histogram shows the sources of microplastics that enter the sea in that form, not including the 70 to 85 per cent that enter as litter (7 December 2019, p 38).
- The motor in an electric car is an example of a moving magnet giving rise to an electric field only when it becomes a generator for the purposes of regenerative braking (30 November 2019, p 42).

Want to get in touch?

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40 years ago, *New Scientist* was pondering whether the dinosaurs met a cataclysmic end

THE story might almost have begun with "once upon a time". "About 65 million years ago, at the end of the Cretaceous Period, a wayward Apollo-type asteroid ploughed into our planet and was responsible for wiping out the dinosaurs and many other forms of life on Earth," we wrote in our 10 January 1980 issue.

Our correspondent was reporting from the annual meeting of the American Association for the Advancement of Science in San Francisco. There, a team of California-based scientists led by Nobel prize-winning physicist Luis Alvarez and his geologist son Walter Alvarez first publicly proposed a truly Earth-shattering explanation for one of life's most enigmatic episodes – a mass extinction that had apparently wiped out many of the planet's species, including the then-dominant dinosaurs.

"The theory is supported by the discovery of large concentrations of iridium in rocks from the Gubbio Valley in Italy and near Copenhagen in Denmark," we wrote. The sheer amount of this element, rare on Earth but relatively abundant in some space environments, suggested the impact of an extraterrestrial rock 7 to 10 kilometres in diameter, the team proposed.

The 100 million megaton explosion "would make a 175 km diameter dent in the crust and material 100 times the object's mass would be thrown skyward. The resulting darkness would suppress photosynthesis, and give rise to the pattern of extinctions observed in the fossil record," we wrote.

This compelling story was bolstered in the early 1990s by the discovery of the 150-kilometre-wide Chicxulub crater, found partially on Mexico's Yucatán peninsula and partially under the sea to the north. Not only was the crater about the right size, but the site also proved rich in iridium, providing conclusive evidence that the clay layer on the Cretaceous–Paleogene boundary represented debris from an asteroid impact.

Too good to be true? A cartoon accompanying our initial report wondered whether the whole idea had been invented by Hollywood. There are some who still nurse that suspicion, casting doubt on whether the precise timing of the impact means it can be responsible. But for most, the seemingly science-fiction tale of a space rock doing for the dinosaurs is now firmly established as science fact. Simon Ings

To find more from the archives, visit newscientist.com/old-scientist

A feast for your mind over the next year

Liz Else and **Simon Ings** on the cultural treats to come in 2020 – starting with non-fiction books

The mysteries of growth

HOW did we get to be who we are? From what did we emerge? And what are we becoming? This year sees the publication of some fascinating books about how animals develop.

The Black Box of Biology: A history of the molecular revolution (Harvard University Press) by historian Michel Morange weaves together the science of cellular life, from charming early chemical explanations of how life works to the dizzying complexities of computational biology.

There is more to discover about this fascinating story, says Alexander Levine, whose *Living Matter: Seeking new physics in the biological world* (Princeton University Press) argues that life's complexity and capacity for self-organisation may require a new branch of physics.

What amazing force puts 40 trillion cells (more cells than there are stars in the galaxy) into the right order to make a human? In *The Dance of Life: Symmetry, cells and how we become human* (W.H. Allen), Magdalena Zernicka-Goetz at the University of Cambridge and former *New Scientist* editor Roger Highfield reveal answers, some with profound implications for the future of pregnancy.

A few decades ago, there were no effective ways to care for very premature babies. Now even infants born weighing less than half a kilogram have gone on to have full, healthy lives. In *Early: An intimate history of premature birth and what it teaches us about being human* (Fourth Estate), Sarah DiGregorio tells the complete story of this new, life-saving science.

Yet it is by no means obvious why a species as complex and distractable as ours should love our children. *Strange Situation: A mother's journey into the science of attachment* (Ballantine) describes Bethany Saltman's decade-long journey through labs, archives and training sessions to reveal surprising and sometimes awkward truths about our supposed "instinct" for attachment.

Not that such questions are unique to our species. In *Wildhood: The epic journey from adolescence to adulthood in humans and other animals* (Scribe), Barbara Natterson-Horowitz and Kathryn Bowers trace teen angst through the animal kingdom, and discover that young humans aren't the only animals who have trouble getting along in a group, or in their search for status and that special someone.

Making sense of everything

The world is too big for us to get our heads around it all, but these books will help us attempt the impossible.

To understand anything, we first need to put it in some sort of order. A sense of direction is essential to the development of intelligence. Does this mean our world of automated travel and route-dictating apps is making us stupid? Michael Bond investigates in *Wayfinding: The art and science of how we find and lose our way* (Picador).

Gaming in 2020

Cyberpunk 2077

CD Projekt Red (out in April)

This game promises to let you live the *Blade Runner* dream.

Half-Life: Alyx

Valve (March)

The latest in a great series, and possibly the definitive VR game.

Halo Infinite

343 Industries (end of 2020)

This continues the sci-fi adventures of Master Chief on the new Xbox console.

The Last Of Us Part II

Naughty Dog (May)

Returns players to a stunning post-apocalyptic world.

Watch Dogs: Legion

Ubisoft (March)

Brings high-tech hacking to a post-Brexit London.

London Games Festival

From 26 March

More than 100,000 people are expected at its events.

Jacob Aron

Why do we sneer at astrologers, but lap up the pronouncements of economists? Both draw unprovable stories from intractably huge data sets, and, as Alexander Boxer's *A Scheme of Heaven: Astrology and the birth of science* (Profile) reveals, they may have more in common than you ever suspected.

Once upon a time, it was just about possible to know everything (you still had to be a genius, though). In *The Polymath: A cultural history from Leonardo da Vinci to Susan Sontag* (Yale University Press), Peter Burke traces the rise and fall of these intellectual giants, and explains why we will probably never see their like again.

The Alchemy of Us: How humans and matter transformed one another (MIT Press) makes hay with the idea that we are inveterate tinkerers, explaining the things around us by comparing them with the things we make. Physicist

AILBHE O'DONNELL/GETTY IMAGES

Piano playing can be harder if you can't make sense of your sheet music

Ainissa Ramirez tells how clocks, steel rails, photographic film, light bulbs and silicon chips ended up shaping how we look at the world.

The Matter of Facts: Skepticism, persuasion, and evidence in science (MIT Press) by father and son writing team Gareth and Rhodri Leng combines their research in science and politics to explain why science is such a delicate and difficult business. They also have ideas on how best to defend it against complacency, corruption and cheap shots from outsiders.

When famous scientists get to a certain age, they invariably start wondering what their work has been about. Bestselling physicist Brian Greene is no exception. In *Until the End of Time: Mind, matter, and our search for meaning in an evolving universe* (Allen Lane), he explores how life and mind emerged from chaos, and how science, stories, myth, religion and creative expression all contribute to our ideas of truth.

Bendable brains

Understanding ourselves is even more difficult than wrapping our heads around the universe.

In *The Future of Feeling: Building empathy in a tech-obsessed world* (Little A), journalist Kaitlin Ugolik Phillips wonders what social media, artificial intelligence, robot technology and the digital world are doing to her relationships. Doctors, entrepreneurs, teachers, journalists and scientists suggest how we can enjoy technology without ruining our lives.

Ruination is a real possibility, according to Rose A. Dyson, whose *Mind Abuse: Media violence and its threat to democracy* (University of Chicago Press) blows the whistle on an industry that she claims is profiting from a public crisis in mental health.

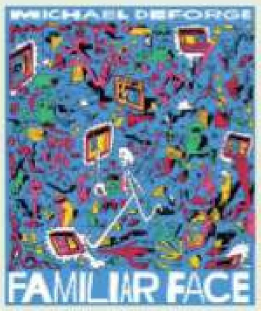
There is a lot of money to be made in media, and graphic violence, so why should we take on trust reassurances that media violence doesn't do us any harm?

Julia Ebner, who works at a counter-extremism think tank, discovered the terrifyingly violent assumptions underpinning some very ordinary lives when she went undercover to discover how extremists live. She tells her story in *Going Dark: The secret social lives of extremists* (Bloomsbury).

Maybe pills are the answer. No, really. After all, if disappointment is too much for you, or if your long-term partner is rubbing you up the wrong way, you can already cure the problem with a pill, say ethicists Brian D. Earp and Julian Savulescu in *Love is the Drug: The chemical future of our relationships* (Manchester University Press).

Such is the state of today's pharmaceutical art, we had all better start asking questions about the value of love, before we end up medicating it.

A look at the science fiction of 2020



Familiar Face

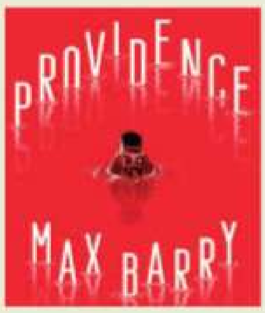
Michael deForge
(Drawn & Quarterly)
This graphic novel, reminiscent of the work of Lisa Frank and Keith Haring, constructs a Kafkaesque plot around how familiar things can become unrecognisable in a heartbeat.

QualityLand

Marc-Uwe Kling (Orion)
An amusing skewering of the logical consequences of the world's increasing efficiency and optimisation.

Agency

William Gibson (Viking)
"The future is already here, it's just unevenly distributed." Gibson's new time travel series – this is the second book – is an entertainingly literal take on his famous futurist throwaway remark.



Providence

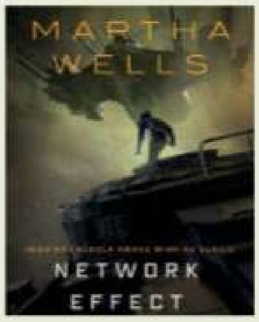
Max Barry
(Hodder & Stoughton)
A *Starship Troopers* set-up with extragalactic aliens and a scrappy band of space-force kids sent to fight them. Barry's 2013 book *Lexikon* was a blast, so fingers crossed this one will be too.

Gathering Evidence

Martin MacInnes
(Atlantic Books)
This book is mooted to be one of the best of 2020, featuring bonobo crime and one man's head trauma in an extinguishing world.

Exercises in Control

Annabel Banks (Influx Press)
A debut collection about the human obsession with control. No matter how normal the opening scenario, each of these stories ends in the strangest place.



Network Effect

Martha Wells (Tor)
At last, there is a book-length Murderbot tale! This socially anxious biohybrid killer robot with a heart of gold serves up kick-ass soup for the introverted soul.

Greenwood

Michael Christie (Scribe UK)
A lyrical, meditative take on a world in which forests have become such rare commodities that they are turned into therapeutic retreats for the very wealthy.

The Hidden Girl and Other Stories

Ken Liu (Head of Zeus)
The award-winning author's new collection of short stories features a mix of science fiction and fantasy and a new novelette.

Sally Adee

Food: a new relationship

The list of what we don't know about food looks terrifyingly long. At the personal level, there is *Ingredients: The strange chemistry of what we put in us and on us* (Dutton) by science communicator George Zaidan. He is big on everything from how bad processed food really is and the question mark over coffee, to what happens if you overdose on fentanyl in the sun, and asking if cassava plants and Soviet spies have anything in common.

Food Adulteration and Food Fraud (Reaktion) by Jonathan Rees also shows what we should watch out for. His account of the journeys of some food to the shop encompasses horsemeat in the UK, honey-laundering in the US and 40-year-old zombie meat in China. It speaks of hidden crimes by large food processors and small-time criminals. Rees warns us against our willingness to ignore such deception if products are cheap enough.

That cheapness gets even more worrying when you factor in climate change and population growth. Explanatory guides are badly needed, so welcome *The Future of Food: How digital technology will change the way we feed the planet* (Allen Lane) by Caleb Harper. Harper recounts his work at the MIT Media Lab, where as a principal research scientist he monitors variables affecting plant health, including water, light, carbon dioxide and temperature. He is still optimistic that we can feed 10 billion mouths (and counting) by 2050.

Tim Lang's *Feeding Britain: Our food problems and what to do about them* (Pelican) pulls no punches as he assesses the strengths and fragilities of UK food production. Lang, a professor of food policy at City, University of London, reckons it is time to set a new course for UK food – especially with Brexit.

We may end up having to mimic what animals do, to play with the message of *Eat Like the Animals: What nature teaches us about the science of healthy eating* (Houghton Mifflin Harcourt) by David Raubenheimer and Stephen Simpson. It is true we have trouble doing what a blob of slime mould and baboon do instinctively – eat for optimal health. Fortunately, the authors say our appetite can be hacked for our own good.

> "We have trouble doing what a blob of slime mould and a baboon do instinctively – eat for optimal health"

Don't miss these events

First Animals

Museum of Natural History, Oxford, until 24 February
Go back 600 million years to meet our earliest ancestors.

Leonardo da Vinci

Louvre, Paris, until 24 February
Europe's largest and most comprehensive exhibition of the polymath's work.

Making Marvels: Science and splendor at the courts of Europe

Metropolitan Museum, New York, until 1 March
Revisit the days when scientific devices were also lavish status symbols, coveted by royalty.

Mushrooms: The art, design and future of fungi

Somerset House, London, from 31 January
Artists, musicians and designers celebrate fungi's potential to transform our world, from the inside out.

SEANA GAVIN, 'MINDFUL MUSHROOM'; COURTESY OF THE ARTIST/SOMERSET HOUSE

Alice in Typhoidland

History of Science Museum and other Oxford sites, from 21 January
Join Alice Liddell – Alice in Wonderland – on a murky tour of Oxford, and discover the secrets of a gruesome and dank disease.

Nirin: 22nd Biennale of Sydney

Sites in New South Wales, Australia, from 14 March
Indigenous Australian activists and artists from around the world explore sovereignty on a fast-changing planet.

Simon Ings

Living with climate change

The best we can do about climate change is to get smart with mitigation and adaptation while keeping optimistic.

Flying the flag for realpolitik are former UN climate secretary (and architect of the Paris agreement in 2015) Christiana Figueres and Tom Rivett-Carnac, her UN political strategist. In *The Future We Choose: Surviving the climate crisis* (Manilla Press), they outline life in 2050 if we fail to meet the Paris targets – and life in a carbon neutral world. Act now, and it could yet be our finest hour.

Danny Dorling's *Slowdown: The end of the great acceleration – and why it's good for the planet, the economy, and our lives* (Yale University Press) offers a different kind of optimism. Dorling welcomes the current slowdown of population growth, economies and tech innovation because it moves towards stability.

Environmental justice is another paradoxical reason to be cautiously cheerful, with Julie Sze's *Environmental Justice in a Moment of Danger* (University of California Press) laying out the precarious environmental and political moment in a primer

Current ways of growing vegetables might not be enough to feed everyone

ANUCHA SIRIVISANSUWAN/GETTY IMAGES

packed with hopeful stories.

Getting dirty with the detail, though, may yet prove the safest place to look for hope, so try *The Citizen's Guide to Climate Success: Overcoming myths that hinder progress* (Cambridge University Press) by Mark Jaccard, and *Building a Resilient Tomorrow: How to prepare for the coming climate disruption* (Oxford University Press) by Alice C. Hill and Leonardo Martinez-Diaz.

If you actually want to give in to despair, it is hard to beat *Bunker* (Allen Lane) by Bradley Garrett. Its subtitles, *Prepping for the collapse of civilization* (US) and *Building for the end times* (UK), say it all.

Tracking the future

As ever, predicting the future is a mug's game. So smarter books go for caution. Take *A World Without Work: Technology, automation and how we should respond* (Allen Lane) by Daniel Susskind, a former policy adviser to the UK Cabinet. When he says jobs are really going this time, he is careful to add that the challenges will be to fairly distribute wealth generated by automation, constrain the powers of big tech firms and provide meaning for people used to work.

Then there is economics, now a rather wonky discipline – as shown in *What's Wrong with Economics?: A primer for the perplexed* (Yale University Press) by economic thinker Robert Skidelsky.

Why economics really matters is illustrated in *Deaths of Despair and the Future of Capitalism* (Princeton) by Anne Case and Angus Deaton. Life expectancy in the US fell for three years in a row recently, and in the past two decades, deaths from suicide, drug overdose and alcoholism rose dramatically, and are still rising.

The authors argue that the capitalism that lifted countless people out of poverty is now destroying blue-collar America. They have solutions to make it work for all. They had better be right.

Elsewhere, enjoy some left-field offerings, with *Uncanny Valley: A memoir* (Fourth Estate) by Anna Wiener taking us back to Silicon Valley circa 2012, when casual sexism and excess were the hallmarks of Valley start-ups.

Then there is *Coding Democracy: How hackers are disrupting power, surveillance, and authoritarianism* (MIT Press) by Maureen Webb, which says hurrah for the hackers who are inspiring activism that may let ordinary citizens take back democracy.

Back with work, Erin Hatton's *Coerced: Work under threat of punishment* (University of California Press) asks what prison labourers, graduate students, welfare workers and college athletes have in common. Hatton says they are all part of a growing workforce of coerced labour. For them, employment means workplaces without protections like unions, where employers wield punitive power far beyond the ability to hire and fire. Because this is commonplace, Hatton says that coercion – as well as precarity – is a defining feature of work in the US. Strong stuff for a new decade. ▮

Film highlights for 2020

January

Underwater

Kristen Stewart finds herself in (very) deep water in this superior *Alien* homage by *The Signal* director William Eubank.

February

Little Joe

Austrian newcomer Jessica Hausner directs Ben Whishaw and Emily Beecham (pictured above) in this splendidly unsettling tale of a plant geneticist who says it with flowers – and not in a good way.

February

The Invisible Man

Director Leigh Whannell turns H. G. Wells's existential horror story into a #metoo-flavoured nightmare. Elisabeth Moss plays a woman being hunted by an abuser that nobody else can see.

March

Radioactive

Rosamund Pike (pictured above) plays Maria Skłodowska-Curie (Marie Curie) in a biopic based on the graphic novel by Lauren Redniss. It is directed by Marjane Satrapi, also a graphic novelist.

March

Vivarium

Jesse Eisenberg and Imogen Poots look for the perfect home and find themselves trapped in a mysterious, labyrinthine suburb – a tip of the hat to *The Twilight Zone*, perhaps?

April

Proxima

The lone woman on a team of astronauts agonises over the care of her 7-year-old daughter. The premise to Alice Winocour's film may sound over-worthy, but industry buzz suggests a gripping, intelligent attempt to redefine "the right stuff". Eva Green and Matt Dillon star.

October

BIOS

There is an irresistible aura of nostalgia around this post-apocalyptic tale of an ailing inventor (Tom Hanks) who creates a robot to look after his dog, and gets more than he bargained for.

December

Dune

Denis Villeneuve, who directed *Arrival* and *Blade Runner 2049*, tackles Frank Herbert's celebrated and notoriously hard-to-film novel *Dune* (or the first half of it, at any rate).

And later this year...

Stowaway

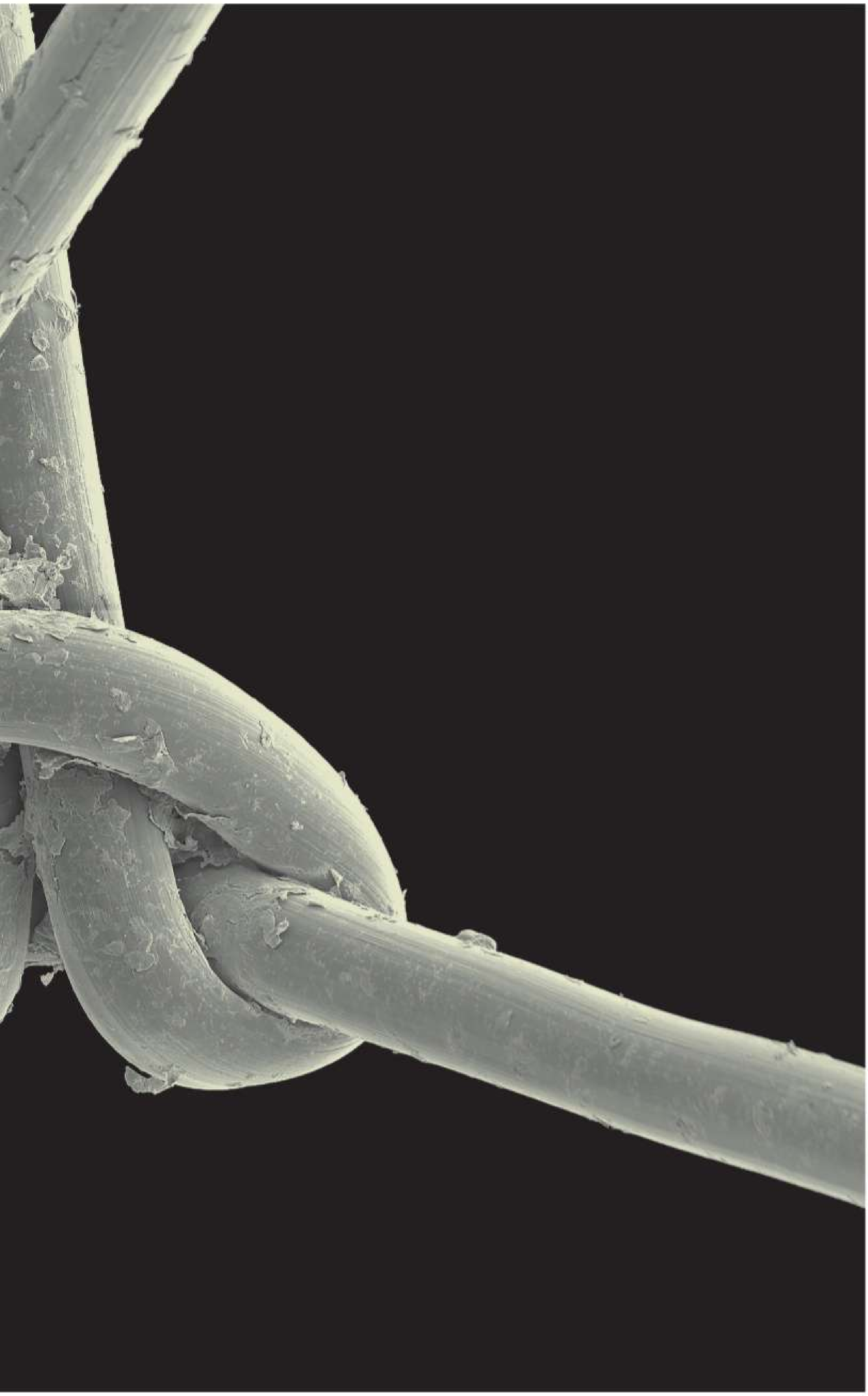
Joe Penna directs Anna Kendrick and Toni Collette in a cautionary tale of what happens to your rocket when you find yourself carrying a whole extra person.

Chaos Walking

Charlie Kaufman (*Being John Malkovich*) pens this adaptation of Patrick Ness's young adult series about telepathy run amok. Doug Liman directs.

Simon Ings

TOP: BFI; BOTTOM: WORKING TITLE FILMS



A healing knot

Photographer Anne Weston

IF YOU have ever had a small wound stitched up by a doctor, you will probably have taken this minor medical procedure for granted. Yet this image reveals the full Byzantine beauty of a single stitch when it is magnified 100-fold using an electron microscope.

Anne Weston, a microscopist at the Francis Crick Institute in London, took the shot. She says her image "shows in great detail the skill required by healthcare professionals to accurately tie such an intricate knot with a piece of thread less than 0.25 millimetres in diameter".

The opportunity to shed greater light on this often-overlooked aspect of medicine came when she needed stitches herself, after a small cyst was removed from her head. When she was due to have the stitches taken out, Weston turned up at the hospital with a small pot of fixative used to preserve and protect samples for microscopy, surprising her doctor. The tiny fragments clinging to the thread are scraps of her own skin.

While she usually shows microscope images of cells at outreach projects, Weston says that "often, things that we think of as very mundane can look amazing when viewed at high magnification".

This image received an honourable mention in the Royal Society Publishing Photography Competition for 2019.

Clare Wilson

New Scientist Discovery Tours

Amazing science-inspired tours across the globe. Join experts and fellow travellers who enjoy the discovery of science. Secure your place for just £50 deposit during January.

BOOK NOW WITH JUST $99 DEPOSIT

INDIA

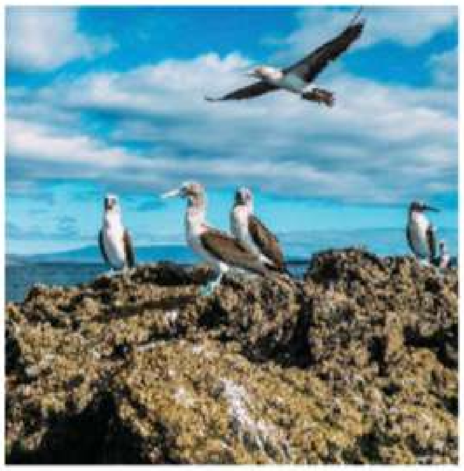
Track snow leopards in the Himalayas

13 days for £6,295 (approx $7,995)

22 March 2021

Endangered, beautiful and elusive, snow leopards are rarely seen in the wild. Working with expert guides, track these solitary creatures in the hidden Himalayas.

ECUADOR



Darwin's Galapagos with Jo Ruxton

11 days for £6,995 (approx $8,885)

7 June 2020

Join our yacht in this paradise for natural history, wildlife and geology. Accompanied by film producer and marine conservationist Jo Ruxton and also visiting the historical mountain city of Quito.

ICELAND

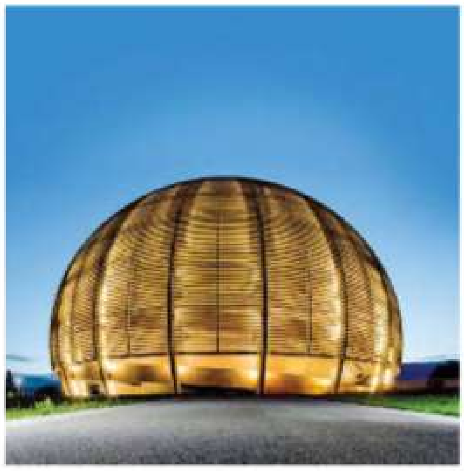
Land of fire and ice

8 days for £2,249 (approx $2,855)

31 October 2020, 7 November 2020

An unforgettable tour of Iceland's majestic landscapes with a leading volcanologist. Marvel at erupting geysers, stunning glaciers, tectonic plates and the aurora borealis.

SWITZERLAND/FRANCE



CERN and Mont Blanc: Explore dark and frozen matter

6 days for £2,699 (approx $3,429)

18 May 2020, 17 September 2020

Visit the Large Hadron Collider at CERN, learn how receding glaciers are revealing history and explore the charming lakeside city of Geneva. Accompanied by experts.

FRANCE

Science of pro cycling: Mont Ventoux

5 days for £2,199 (approx $2,789)

21 May 2020

A highly immersive expert-led training camp with sports scientists and ex-Team Sky rider Phil Deignan, staying in a 4-star chateau in Provence.

Visit newscientist.com/tours for detailed itineraries and how to book

SPAIN

Ancient caves, human origins

7 days for £2,249 (approx $2,855)

18 May 2021, 7 September 2021

Step back over 10,000 years to discover how our ancestors played, lived and worked. Visiting caves from pre-history plus beautiful towns and great food in the company of *New Scientist* editors.

CZECH REPUBLIC

Kepler's Prague: Music of the spheres

6 days for £1,968 (approx $2,499)

14 April 2020, 14 September 2020

Follow in the footsteps of Johannes Kepler and Tycho Brahe, as we unearth the connection between music and orbits of the planets in the city of a hundred spires.

MADAGASCAR

Wildlife of Madagascar

12 days for £6,595 (approx $8,375)

11 September 2021

Experience Madagascar's unique and diverse ecosystem by plane, boat and authentic bush camps. Accompany rangers and meet animals seen nowhere else.

ITALY

Science of the Renaissance

7 days for £1,825 (approx $2,319)

3 March 2020, 3 November 2020

Encounter the great scientific minds and discoveries of the Renaissance on a cultural adventure across the pre-eminent cities of science: Florence and Bologna.

JAPAN

Japan: Nature, culture, science

12 days for £6,695 (approx $8,499)

18 October 2020

Discover Japan on a journey taking in Tokyo, Hakone, Kyoto and Kagoshima. Travel from snow-capped mountains to the buzzing metropolis; from future technology to volcanic islands.

INDIA

Tiger conservation safari

9 days for £3,850 (approx $4,889)

10 April 2021

Visit the reserves of Pench and Tadoba in search of the Bengal tiger. Staying in award-winning lodges and encountering India's varied wildlife by jeep, bike and on foot.

USA

Space: Past & future

15 days for £5,279 (approx $6,699)

14 days for £4,799 (approx $6,095)

6 May 2020, 14 September 2020

A comprehensive USA tour visiting key sites in the history and future of space exploration, including NASA space centres and the Virgin Galactic spaceport.

KENYA

Kenya: Cradle of humanity

9 days for £3,299 (approx $4,190)

February 2021

Explore the origins of humanity on this unique and adventurous archaeology and wildlife tour in the heart of Kenya.

Visit newscientist.com/tours for detailed itineraries and how to book

The Veganuary experiment

Turning vegan is good for the body and the planet, but giving up all animal products can be tough. Is a short, easier stint of plant-based eating still worthwhile? **New Scientist** investigates

“I had to go dairy free when I was breastfeeding three years ago. It sent me into a panic and I had to totally overhaul my diet. I lived off coconuts. It looks a lot easier to be dairy free now.

JANUARY is the time of year when many of us take a rain check on our indulgences. We politely wave away puddings, gyms heave with new recruits and plenty of us lay off the booze. This year, it is estimated that at least 1 million people will do something even more challenging: eat a vegan diet for the month.

Choose to follow suit and you can forget about that juicy bacon sandwich, say goodbye to scrambled eggs and there will be no more milk in your coffee. It is a challenge not to be sniffed at. But it is a worthy one: the evidence suggests that, done carefully, veganism is good for our health and great for the planet.

Perhaps that explains the growing trend towards part-time veganism, of which Veganuary is just one example. The vegan before 6 pm (VB6) diet is gaining popularity in the US, principally as a means of losing weight. And the meat-free Mondays campaign is also getting traction, with more restaurants offering vegan options as well as vegetarian ones. “The thought of never eating meat again is, for most people, overwhelming,” says Toni Vernelli at Veganuary, a UK charity. A part-time vegan diet is more manageable and surely offers a portion of the same benefits.

Or does it? It is conceivable that some of those who dip briefly into vegan eating might not get the right balance of nutrients. With a lack of experience in making vegan meals, it is easy to opt for pre-prepared dishes, which may cancel out the positives. Can you really be a casual vegan and still reap the benefits?

THE VOLUNTEERS
Our 19 volunteers explain how they felt before going vegan (this page) and how they got on during the trial (page 35). Some of them ended up developing vegan habits that persisted beyond the end of the experiment (page 37).

“I’m curious how I’ll survive. Confession: I made sure gin and tonic is vegan before agreeing – can’t live without that!

> “I have been vegetarian in the past, probably eat meat one or two times a week in small quantities now. But I consume vast quantities of dairy and eggs...

iSTOCK VIA GETTY IMAGES

The experiment

To find out, we teamed up with researchers from the Livestock, Environment and People (LEAP) programme at the University of Oxford to run a pilot experiment. A band of 19 *New Scientist* staff kept strict food diaries for a fortnight, eating their usual diet for the first week and sticking to veganism for the second. We used an app called MyFitnessPal to keep track of the food in detail. Most of the group were full-blown meat eaters, but there were three pescatarians and three vegetarians, which gave us a hint of the different benefits of swapping diet for different groups.

The LEAP researchers then analysed our diaries to see the effects on the environment (see below) and our nutrition (see page 36). More research will be needed to confirm what we found, but, as far as we know, this is the first study of its kind, involving real food diaries from people dipping their toes into veganism.

SAVING THE ENVIRONMENT

By Alison George

“I eat meat most days. I live for a well-cooked steak at the weekend and can’t imagine a life without yogurt, milk and cheese.” These were the words of one volunteer just before our vegan experiment. Facing up to the reality of a meat and dairy-free existence can be daunting. But if you are concerned about the climate crisis, giving up animal products is one of the key things individuals can do to help.

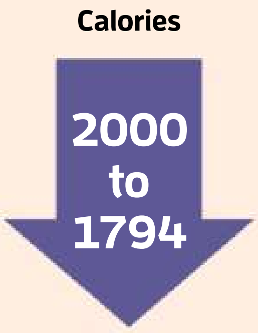
It isn’t hard to see why veganism is better for the planet than other diets in principle. If you eat a plant, that is more efficient than taking a plant, feeding it to an animal – which makes tissue from it and belches out greenhouse gases in the process – and then eating the animal. “A large amount of crops are used to feed animals. It’s inefficient,” says Michael Clark, who is part of the LEAP programme. This goes for dairy products too. Indeed, cheese typically has a higher carbon footprint than the equivalent weight of pork.

Calculating the carbon footprint of food is no simple matter, however. Most assessments of the impacts of our eating habits start with hypothetical diets. Once researchers have compiled a list of foods, they estimate all the carbon emissions associated with the production of each one, including the use of fertiliser, pesticides, land and fuel. This information can then be used to calculate the total environmental impact of a food.

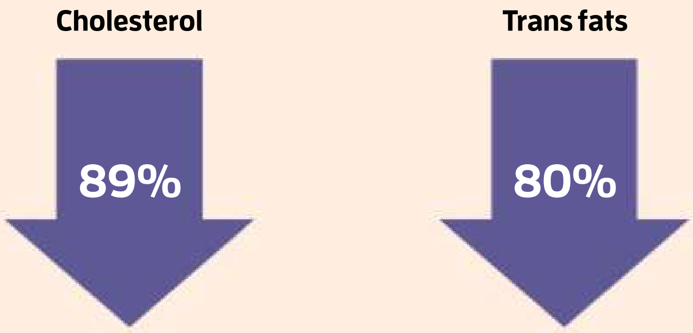
Carbon dioxide isn’t the only greenhouse ›

Vegging out

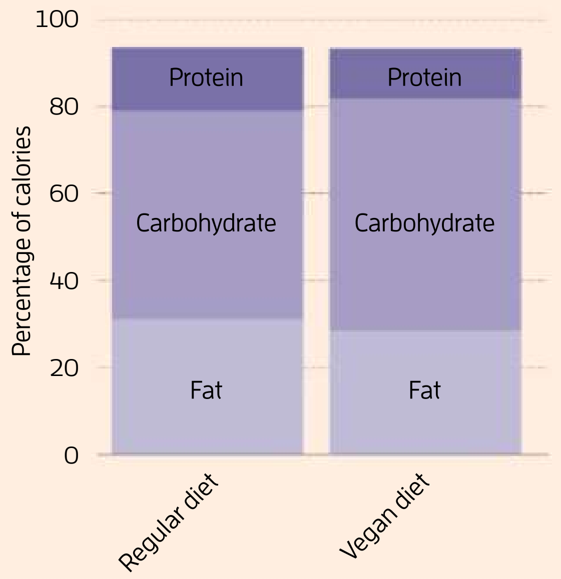
We got 19 people (13 meat eaters, three pescatarians and three vegetarians) to record what they ate for one week as part of their usual diet and then for a second week eating a vegan diet



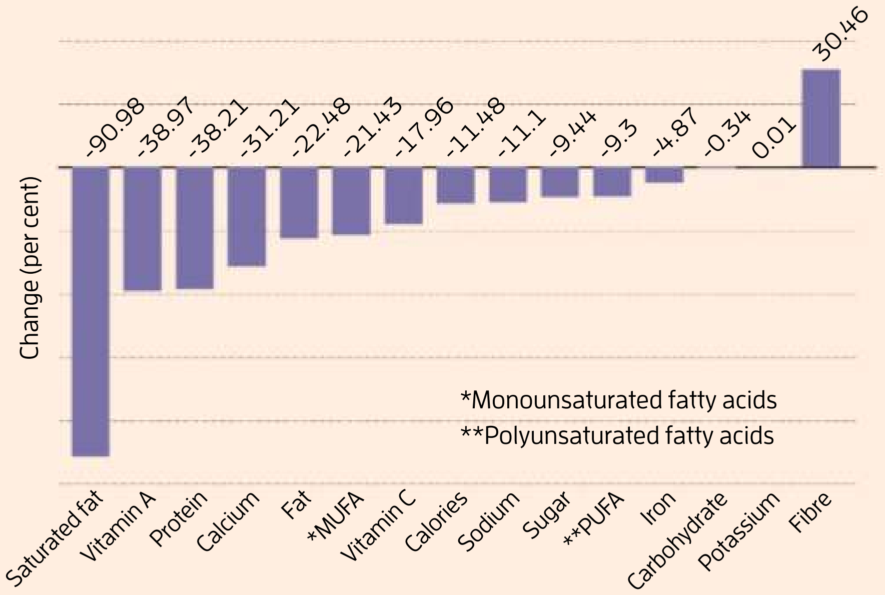
On average, daily calorie intake went down by 10 per cent



The balance of major nutrients remained similar, but the proportion of calories coming from carbohydrates grew at the expense of fats and proteins



Fibre intake was boosted, and cholesterol and trans-fatty acid consumption dropped hugely (see arrows, above), which is good, but the consumption of many important nutrients went down too



gas emitted during these processes. There is also methane, which is 25 times as potent as CO_2 – albeit shorter-lived in the atmosphere – and nitrous oxide, which is about 300 times as potent. Studies tend to wrap these gases together in units of carbon dioxide equivalent (CO_2e), the quantity of CO_2 that would be needed to give the same greenhouse effect.

One of the most comprehensive studies of this type was conducted in 2018 by Joseph Poore at the University of Oxford and Thomas Nemecek at the Agroscope research centre in Zurich, Switzerland. They looked at a data set covering 119 countries and including products that represent 90 per cent of all human calorie intake. This revealed that the environmental impact of all foods was greater than previously thought, but especially that of animal products.

Meat and dairy contribute about 60 per cent of agriculture's greenhouse gas emissions, and provide only 18 per cent of our calories. "We calculated that cutting out animal products would reduce the greenhouse gas emissions of food systems by 49 per cent. That's incredible cost-cutting," says Poore. A 2016 analysis of the food diaries of 153 Italian adults reached a similar conclusion: established vegans had a dietary carbon footprint that was 34 per cent lower than that of meat eaters. Would our experiment on part-time vegans back this up?

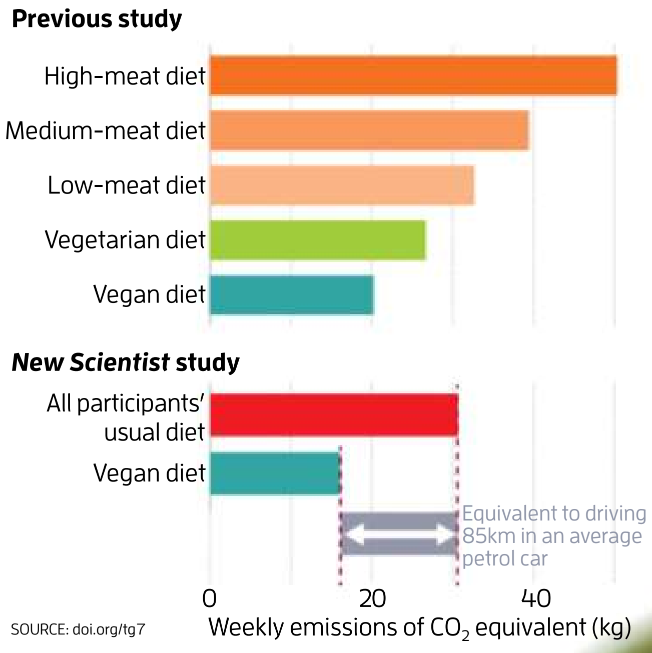
In general, yes. On average, there was a 53 per cent fall in greenhouse gas emissions when participants ate a plant-based diet compared with their usual one (see "Plants for the planet", right).

Things get more interesting when we look at the differences in carbon savings between say meat eaters going vegan and vegetarians doing so. That study of 153 Italians found no difference between the carbon footprint of a vegetarian and vegan diet. "A likely explanation might be that, while unprocessed, plant-based foodstuffs usually replace animal-based products in hypothetical vegetarian and vegan diets, real plant-based diets are instead characterised by highly processed meat and dairy substitutes," says Francesca Scazzina at the University of Parma in Italy, who carried out the study.

Yet our three vegetarians reduced their dietary carbon footprint by 42 per cent on average, showing that serious carbon savings are possible. This aspect of our results can't be the basis for sweeping conclusions because it only covers three people, but it is interesting nonetheless. "We don't realise how much difference we can actually make," says Clark.

Plants for the planet

Previous studies of long-term vegan diets have shown that they are greener than other diets. Our study of part-time veganism hinted at similar effects



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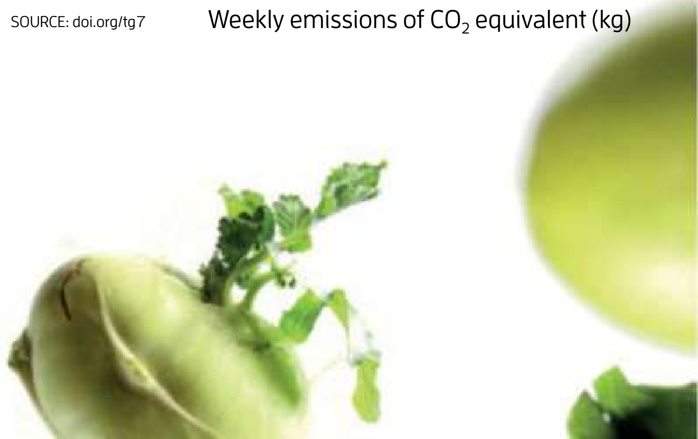


We also looked at the different changes in nutrient intake experienced by meat eaters, pescatarians and vegetarians when they switched to a vegan diet. These findings must be taken with a pinch of salt because we are looking at small numbers of people, particularly when it comes to micronutrients. But the results still contain some interesting hints at how our volunteers fared

ALL DIETS ➡ VEGAN

One of the most striking results across all our volunteers was the huge increase in their fibre intake. On average, they ate 21 grams per day on their usual diets but 30 g per day when eating a vegan diet. This is roughly in line with what we know about vegan eating from previous studies.

MEAT EATERS ➡ VEGAN

Meat eaters might worry about getting less iron if they chomp down less red meat. Our volunteers' food diaries suggested that this group got 5 milligrams a day when eating as normal and 4 mg a day during the vegan week. This suggests they managed to get about the same amount of iron.

PESCATARIANS ➡ VEGAN

You might expect this group to get much less protein. In fact, our pescatarians got on average 65 g of protein per day when eating their usual diet and 67 g when they went vegan. This might be because they thought more carefully about eating other plant-based protein sources, such as tofu.

VEGETARIANS ➡ VEGAN

Dairy products are rich in calcium, so giving them up could lead to a drop in intake. Our vegetarians got 81 per cent of their recommended daily allowance of calcium when eating as usual and 66 per cent when eating vegan foods. Vegans can boost their calcium intake in all sorts of ways, including drinking alternative milks fortified with minerals.

> “ I expected to really miss eating meat and cheese – I didn't. I expected to feel tired and have less energy – if anything it was the opposite.

> “ I found going vegetarian a doddle, so I thought it would be similarly easy going vegan. I was wrong!

> “ Animal products are hard to avoid. Some things I would have assumed were vegan were not. It's easy to forget that something like noodles might contain egg.

To put this in perspective, I worked out how much carbon each of our meat eaters would have saved if they had eaten a vegan diet for a month: 80 kilograms CO_2e. That is the equivalent of forgoing a car journey of roughly 400 kilometres or an 800 km flight, such as between Switzerland and London. Each of our vegetarians would have also saved significant quantities of carbon if they carried on eating vegan for a month, about 40 kg CO_2e or the equivalent of a 200 km drive.

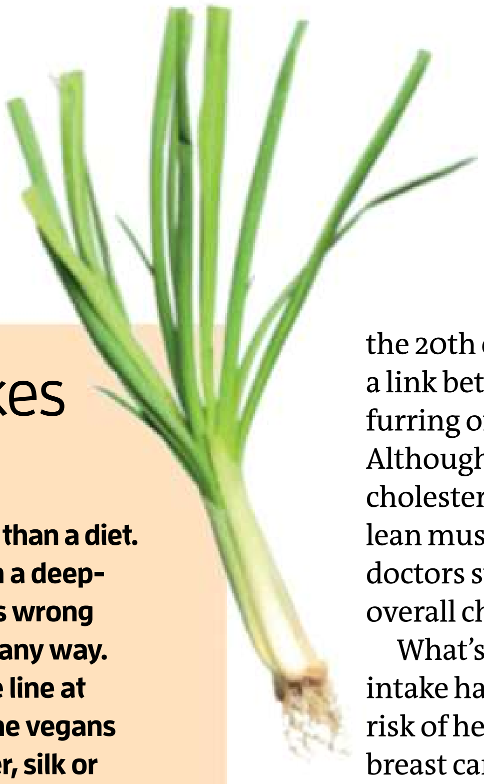
I have been a pescatarian for years and had assumed that the carbon footprint of my diet would be on the smaller side already. I was gobsmacked to find that giving up fish and dairy slashed it in half.

All in, food makes up about a quarter of our carbon footprint, so reducing consumption of animal products is one of the main ways I can reduce mine. Even so – and despite the fact that I love the taste of veggie burgers, tofu and lentils – I don't think I could commit to being a full-time vegan, mainly due to the inconvenience to others I share my meals with. But I'm certainly going to be thinking vegan when it comes to making my lunch at work.

This isn't to say that plant-based foods aren't damaging to the environment. Our study

›

The truth about diet and exercise
Cut through the confusion on 15 January
newscientist.com/events



looked only at the carbon footprint of our diets, but food production degrades the environment in other ways, not least using up water and land. Poore's study found that it can take more water to grow nuts or peas than to produce the equivalent weight of beef. Almonds require particularly large amounts of pesticides and fertilisers. Swathes of forest have been cleared in Asia and South America to grow oil palms.

Still, even the lowest-impact animal products, such as poultry and eggs, tend to be more damaging overall than substitute vegetable proteins such as pulses and nuts. This is also true of the carbon footprint of plant-based milks, made from soya, oats, rice and more. "Even if we could reduce all animal protein products to their lowest impact, it would still be better for the environment to stop eating meat as a protein source," says Poore.

One possible benefit of going vegan part-time could be that it influences people's habits even after they return to omnivorous eating. There is some evidence that abstaining from animal products for a while brings about long-term changes. Unpublished research from consultancy Kantar on the supermarket till receipts of more than 600 people in the UK who gave up meat for January in 2018 found that a year later they purchased less meat and eggs (although their milk and cheese consumption slightly increased).

What of our staff guinea pigs? Did their dalliance with veganism inspire them or send them running to the nearest steakhouse? An informal survey two months after our trial found that many had largely returned to their former eating habits, but there were lasting impacts to the benefit of the planet, as the quotes sprinkled around these pages show.

In future, it might be even easier to reduce the carbon footprint of our diet, with the advent of new foods that bypass the farmyard and field. Milk alternatives might be brewed from yeast in a similar way to beer, real meat could be created through tissue-culture techniques and tasty proteins might be created from thin air using bacteria that suck up CO_2 as they grow. These methods could, in theory, produce meat and dairy products with a fraction of the carbon footprint of those made from plants. Can't imagine going vegan? One day you might not have to. ▮

Alison George is a features editor at *New Scientist*

What makes a vegan?

Veganism is far more than a diet. It is often founded on a deep-seated belief that it is wrong to exploit animals in any way. Still, people draw the line at different points. Some vegans avoid wearing leather, silk or wool. Honey is controversial because some vegans consider it exploitative. Some vegans avoid food grown on animal products, such as mushrooms harvested from chicken manure. Bivalvegans, however, consider it acceptable to eat oysters and mussels on the grounds that they don't feel pain.

In our trial, volunteers refrained from eating any animal product, including all meat, fish, dairy and honey, but weren't expected to take on the entire lifestyle.

NUTRITION BOOST?

By Helen Thomson

As I was chewing on my third vegan ready meal of the week – BBQ "ribs" made from wheat protein (a mistake) – it occurred to me that I probably wasn't doing this right. I had assumed that going vegan, even for a short period, would mean eating a healthier diet. That, after all, is what studies on full-time vegan diets proclaim. The plant-based diet can help you lose weight, lower your cholesterol, reduce your risk for certain cancers, even add a few years to your life. But it seemed it was all too possible to take unhealthy shortcuts. I swallowed my ribs and wondered how the others were getting on.

To get to the bottom of all this, LEAP researcher Cristina Stewart went through our food diaries with a fine-tooth comb. She calculated our total daily nutrients and worked out what percentage of our calories came from what kinds of foods. It was immediately apparent that our diets changed significantly. In the vegan week, we consumed fewer calories and less saturated fat, carbohydrate and cholesterol, while significantly increasing our fibre intake (see "Vegging out", page 34).

This seems like generally good news. In the 20th century, researchers discovered a link between high cholesterol and the furring of arteries that causes heart attacks. Although we now know that some kinds of cholesterol are bad, and others help build lean muscle and actually clean artery walls, doctors still lean towards keeping your overall cholesterol levels low.

What's more, reducing your saturated fat intake has been firmly linked to a decreased risk of heart disease and lung, colon and breast cancers. The important detail here is what you replace those fats with. If you are swapping them for carbohydrates like white bread and low-fat dairy products, you are less likely to see those benefits, probably because of the increased sugar intake. But if you are replacing them with plant-based products such as leafy vegetables, beans and oats, the health benefits soar.

Another benefit of the vegan week was a boost to fibre consumption from around 21 grams a day to about 30g, which is the recommended daily target in the UK. Our group swapped meat for fibre-rich foods such as beans, lentils, whole grains and vegetables. A high-fibre diet can decrease risk for type 2 diabetes, cardiovascular disease and colon cancer by speeding up the passage of potential carcinogens through the gut and feeding "good bacteria". Emerging evidence has even suggested that a high-fibre diet can help prevent infections and improve mood and memory.

But does a week of vegan eating really make any difference? Probably not, if it is just a week, says Keren Papier, part of the LEAP team. We know that it takes more than a week to change your body mass index and blood pressure, for instance. "That said, most of the changes were really positive, and similar to the dietary changes that we're seeing in long-term vegans," she says. That suggests that regular forays into veganism could put you on the right track for long-term health benefits.

So far, so healthy. But meat, fish and dairy provide essential nutrients. Without these staples, covering all your nutritional bases takes effort. It is recommended that 10 to 15 per cent of our diet is protein, for instance. Without it, we can suffer muscle wastage, find it more difficult to fight infections and be at greater risk of high blood pressure.

Most meat eaters in the Western world get plenty of protein, but it is more complicated for vegans. The proteins in meat are known as "perfect proteins" because they can be broken down into all the essential amino acids that the body can't produce itself. Certain vegetable

New Scientist wishes to thank all of those in the LEAP programme who gave up their time to work on this project

I got into the habit of making vegan sandwiches and it has stuck.

I now try to eat less fish and dairy products than I did. So I use more non-dairy milk in tea and adhere loosely to a VB6 regime – vegan before 6 pm.

I've stayed vegan. It's actually much easier than anticipated, once you have changed your mindset about what you can't eat to what you can.

proteins such as those in soya and gluten fit the same bill. But those from whole grains and legumes are harder to digest, and sometimes certain amino acids are missing altogether from rice, nuts and some cereal crops. However, Stewart points out that our participants were still getting the recommended amount of protein. In general, she says, as long as you eat plant-based protein from a variety of sources this shouldn't be anything to worry about.

Calcium intake also decreased, which over time can lead to brittle bones, tooth decay, cataracts and fatigue. Another potential concern is with omega-3 fatty acids, which keep our cells and cardiovascular system tip-top. Although it wasn't possible to identify this from our food diaries, without meat, vegans can lack these fatty acids. Vegans can find them in chia and flax seeds, and some nuts and leafy veg, but often take supplements to top up. Vitamin B12 is vital to our health too – potentially protecting us from stroke – and because it is made by the bacteria in animals, omnivores don't have to give it much thought. Vegans need to look to fortified breakfast cereals and nutritional yeast to get their supply.

> **"Many no longer see veganism as an all-or-nothing proposition"**

Choline is also an essential nutrient critical to brain health, especially in developing fetuses, but it is found mainly in beef, eggs and fish. Surveys in many European countries show that our choline intake falls short of recommended levels, which is particularly concerning in light of current accelerated trends towards plant-based diets, says Emma Derbyshire at consultancy Nutritional Insight.

There are ways of getting all these nutrients on a vegan diet and you would know them with experience. But that is just what our part-time vegans didn't have. A straw poll showed that our motley crew were aware they would need to find replacements for some of their nutrients, but didn't give it much more thought. "I was aware that getting adequate protein is an issue for vegans, but as it wasn't a permanent lifestyle change, I didn't go all in and make the necessary dietary changes," said one participant.

Part-time vegans might not give as much thought to their diet as full-time vegans, but that may not be a problem if they are likely to be topping up any missing nutrients on non-vegan days, says Papier. A bigger issue might be that as veganism grows in popularity, so too do vegan ready meals – like my cheeky BBQ ribs – and vegan versions of unhealthy snacks. Like their non-vegan counterparts, these can be high in sugar and salt.

Speaking earlier this year, Roger Whiteside, chief executive of UK bakery chain Greggs, whose vegan sausage rolls have become a hit, admitted to trialling veganism for its health benefits, but said he was finding it difficult to make things from scratch. "It would be OK if I had time to cook," he said, "but I don't, so I have to have things that are quick and easy." Many of our part-time vegans also said they turned to quick, unhealthy ready meals instead of making the effort to find new recipes to cook at home.

Not everyone is on board with part-time veganism. The Vegan Society recognises that cutting down on our consumption of animal products can have a lot of positive benefits. However, Dominika Piasecka, a spokesperson for the charity, says that veganism is a deeply seated ethical conviction that killing and using animals is wrong. "It isn't something people can do part-time," she says.

Largely driven by the health and environmental benefits, many people no longer see the issue as an all-or-nothing proposition. If you are one of those thinking about being vegan-ish, you can rest assured that it probably has positive health benefits – particularly if you pay attention to what you might be missing.

For Papier, flexi-vegan eating has got to be a good thing. "If you're doing it for a day each week or one month each year, over time you will have consumed fewer meat-based products, which might have beneficial health effects." Our small trial also suggests that being a part-time vegan might lead to unexpected long-term changes. Many of our participants said they ended up being more thoughtful about what they ate, cut down their meat intake or, in one person's case, "at least stopped putting cheese on everything". ∎

New Scientist consultant Helen Thomson is author of *Unthinkable: An extraordinary journey through the world's strangest brains*

New tricks

The key to a longer, healthier life could lie with 10,000 of our closest companions. **Graham Lawton** investigates

IN THE next few weeks, scientists in the US will begin a remarkable medical experiment. They are seeking 100,000 applicants from all walks of life – young, old, rich, poor, urban, rural, fat, thin, black, white, brown. They will winnow them down to 10,000 and then spend years studying every aspect of their health, including why some of them age better and whether drugs might extend their lives.

During the trial, the subjects will be taken out for walks and have their faeces collected in bags. They will have their tummies tickled, fetch sticks, chase balls, sniff one another's butts and urinate against lampposts. Not because those are part of the experiment, but because the subjects are pet dogs.

The Dog Aging Project, based at the University of Washington in Seattle, has been years in the making but is finally off the leash. First and foremost, it will tell us a lot about the ageing process in dogs, says project leader Daniel Promislow. But the real goal is to understand more about how we ourselves age, and how we might slow it down or even reverse it. It seems our best shot at defeating human ageing will come from studying not ourselves, but 10,000 of our best friends.

The idea of using animals as proxies to study our own ills is nothing new. The edifice of modern human medicine is largely built on

animal experiments, particularly mice altered to get human diseases, which can be used to test treatments. But useful as these are, they can only get us so far. Lab mice aren't humans, and the gulf between them and us is almost always too wide, with most experimental drugs falling by the wayside. Experiments on monkeys and chimps can bridge the gap, but are ethically unacceptable.

Enter *Canis lupus familiaris*. A few years ago, cancer doctors hit on the idea of using domestic dogs as a bridge between mouse studies and human trials, reasoning that owners would be highly motivated to care for their sick dogs and hence – perhaps – happy to consent to them being given experimental treatments. They were right: the lymphoma drug ibrutinib was tested on pet dogs and approved by the US Food and Drug Administration in 2013 partly on the basis of those experiments.

The Dog Aging Project takes the idea of using dogs as medical guinea pigs to the next level. As well as testing a specific drug, it will study all aspects of the ageing process.

Dogs, it turns out, are a great model of ageing. "Pet dogs develop essentially all of the same age-related diseases and functional declines that people do," says Matt Kaeberlein, one of the project's lead scientists. They also share our homes, and hence the same environment – and environment is a key determinant of health. And they have a healthcare system that is second only to ours, with their vets often keeping detailed medical records. Another plus is that owners tend to be diligent about giving their dogs medication so compliance can be better than in a human trial. And, crucially, most dogs only live about 8 to 12 years, so can tell us about the ageing process in a much shorter time than humans.

Once the 10,000 dogs are recruited, they will be followed for the rest of their lives. "Our first goal is to understand the biological and environmental factors that determine whether dogs are healthy agers or non-healthy agers," says Promislow. "Can we come up with some metrics so a vet can say, 'your dog is ageing extremely well', or 'there are some problems here we need to figure out'?"

As well as regular surveys of the owners and veterinary check-ups, all 10,000 dogs will have their genomes sequenced. "One of the things that makes dogs a terrific model of ageing is that they show tremendous diversity, not just in size, shape, coat colour and behaviour but also in the diseases they get," says Promislow. "Some breeds get heart disease but never get cancer, some get cancer but never get heart disease. There are long-lived breeds and short-lived breeds. All that diversity creates a great opportunity for us."

About 1000 dogs will also have several other "omics" done: the epigenome of modifications to their DNA; the microbiome of the microbes living in them; and the metabolome of molecules that their bodies produce. These are also thought to influence the ageing process, although how they do it is unknown.

But as well as learning about ageing in dogs, the trial will teach us a lot about ourselves. "There's no question that we will have a direct impact on the health of pet dogs," says Kaeberlein. "But we anticipate that the ageing process in dogs will share features with the one in humans, so I think a lot of what we learn will be directly applicable to human health."

"Dogs certainly age more quickly than people," says Linda Partridge , a director at the Max Planck Institute for Biology of Ageing in Germany, who isn't involved in the project. But they age in a similar way to humans, she says, "and are very social, like humans". ›

"The Dog Aging Project is finally unleashed, and might help defeat human ageing"

GANDEE VASAN/GETTY IMAGES

From a human perspective, perhaps the most exciting leg of the project is a small experiment called TRIAD, which will put 500 dogs through a placebo-controlled clinical trial of rapamycin, a drug that is considered one of the best candidates for a general purpose anti-ageing medicine in humans.

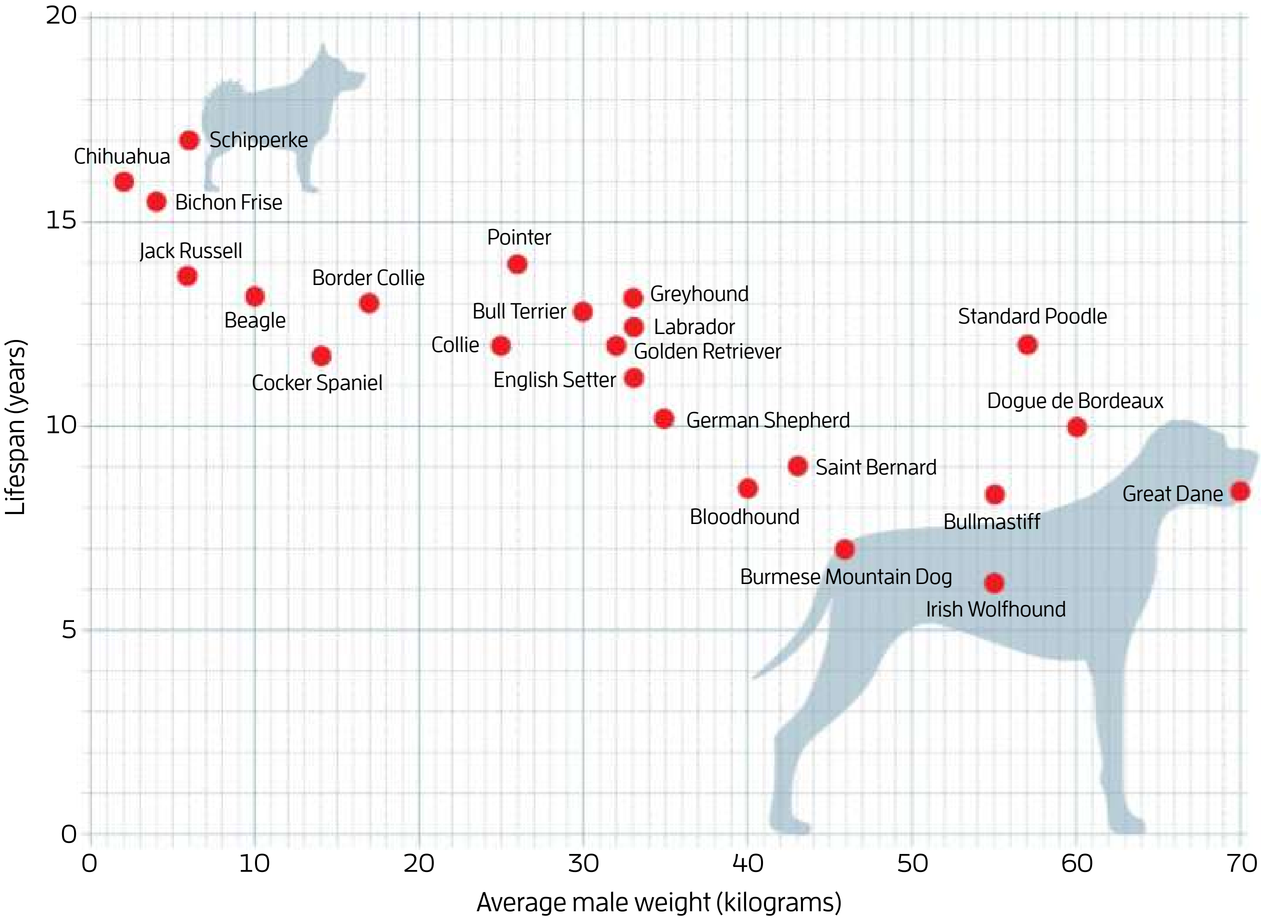
Rapamycin was developed to suppress the immune system so people's bodies would accept transplants, but at small doses it has repeatedly been shown to delay ageing and promote longevity in lab animals. "Of the many molecules that extend lifespan in lab organisms, rapamycin is the most reliable and has the largest effect," says Promislow.

The team will recruit healthy middle-aged dogs aged 7 or over and give half of them small doses of rapamycin three times a week for three years; the rest will be given a placebo. The dogs will then be monitored for up to a decade to see if the drug had any effect on longevity or the onset of age-related diseases. The study has been designed so that, statistically, it should be able to detect any changes to the dogs' lifespan within three years of stopping the treatment.

How much of a lifespan boost the dogs might get is unknown, but if mouse research is

Live big, die young

Dogs show a huge variation in body size, and big breeds tend to die younger. This is because age-related deterioration occurs more rapidly in larger breeds



Dogged devotion

Clive Wynne has figured out what makes dogs unique among animals – and it isn't their smarts, he tells **Tiffany O'Callaghan**

CLIVE WYNNE has long been fascinated by other creatures' minds. He studied the behaviour of pigeons, rats and marsupials, but came to realise that he was more interested in how people and other species interact with each other. So he shifted his focus to dogs, the animal we have the longest and most intimate relationship with.

At that time, the idea was emerging that what makes dogs unique is their ability to read human gestures. It began with a simple experiment: a piece of food is hidden under one of two cups, but the dog doesn't know which. A human then points at the cup with the food and the dog follows their gesture to it. Simple enough, right? Yet experiments showed that other species, even chimps, couldn't do it.

Clive Wynne founded the Canine Science Collaboratory at Arizona State University and is director of research at Wolf Park, Indiana. His new book is *Dog is Love*

COURTESY QUERCUS BOOKS

Dogs, it seemed, were geniuses at social cognition.

Yet as Wynne dug into this idea, it started to fall apart. Instead, he began to think that what set dogs apart was something much more woolly: love. As his new book *Dog is Love* details, finding rigorous ways to test this idea wasn't simple.

TO'C: What made you suspicious of "dog genius" – the idea that dogs have a special kind of intelligence for understanding humans?
CW: I don't deny that our dogs are exquisitely sensitive to the things that we do. Certainly, dogs that live with people and are completely dependent on people for the fulfilment of all of their needs are sensitive to everything that a person does. My point is that this isn't something special about dogs. It is something that comes about in any animal that is brought up by human beings in a state of complete dependence.

Tests with wolves helped convince you of this.
When we went to Wolf Park [a research facility in Indiana that houses wolves socialised to humans] in 2007, we were flabbergasted by what we found. We did these simple pointing tests, tests of social cognition, and the wolves were every bit as good at

Go fetch. And show me how to age well too

STEVE SMITH/GETTY IMAGES

anything to go by, then the answer could be a lot. In one widely cited experiment, Kaeberlein's team gave rapamycin to a group of 20-month-old mice, roughly equivalent to 60-year-old humans. They fed the mice small doses of rapamycin for three months, then took them off the drug and waited for them to die... and waited, and waited. Untreated mice in the study enjoyed a fairly standard murine innings of about 30 months. But the treated ones lived significantly longer, an extra two months on average – a long time in the life of a mouse. Some lived much longer. The final survivor died more than two years after the start of the experiment, at the ripe old age of 3 years and 8 months – the equivalent of about 140 in human years. Extrapolated to 7-year-old dogs, that would increase life expectancy by three or four years, says Kaeberlein. For a 50-year-old woman, it adds around two decades.

What, you might think, are we waiting for? Some people aren't waiting and self-medicate with rapamycin. But for it to become a validated longevity drug, it would have to go through clinical trials, which is easier said than done. Imagine trying to repeat the mouse experiment in humans. You would have to recruit a group of 60-year-olds, give half of them rapamycin for nine years and then wait long enough to see if it had any effect. You could be waiting for decades. "It's not feasible to do a clinical trial in people," says Kaeberlein. That is where dogs come in. "Everything happens faster in dogs, so we can learn a lot in a matter of just a few years," says Promislow.

This won't be the first time that dogs have been given rapamycin. The project has already completed a small-scale study involving 24 middle-aged dogs. After 10 weeks on the drug or placebo, the dogs came into the clinic for a physical examination, blood and urine tests and an echocardiogram. The principal goal was to make sure the drug was well-tolerated. "You don't want to hurt anyone's dog," says Kaeberlein. "We didn't see any side effects, which is really important."

The trial wasn't large or long enough to pick up increases in lifespan but it did indicate there may be some health improvements. Dogs given rapamycin had improved function of the left ventricle, the chamber of the heart that pumps blood around the body and which weakens as dogs (and humans) get older. Similar cardiac improvements have been seen in mice given rapamycin. "It is a marker that the intervention is working," says Kaeberlein.

They also saw some other positive, though not statistically significant, changes. Seven out of the 10 dogs on the high dose were reported by their owners to be more energetic and active, and some owners of rapamycin-treated dogs said their pets were more affectionate, which Kaeberlein says may indicate an improvement in cognitive functioning. All

›

it as dogs. We realised that wolves hand-raised by people show sensitivity to what people are doing. The same has been found with bats raised by people, as well as horses, goats and dolphins.

You found a way to demonstrate the difference in sociability between dogs and wolves.
The behaviour test is the simplest thing I've ever done and I still love it. You just have somebody sit in a chair and mark a 1-metre radius circle around the chair, then measure what portion of a 2-minute interval the animal chooses to spend inside the circle.

If you do this with your dog at home, assuming that you and the dog have been separated for a brief period beforehand, you'll find that most dogs spend all of their time inside the circle. For wolves, even when it's people who acted as their parents from when they were puppies, they'll spend about 40 seconds inside. If it's a stranger, no time at all.

Is there evidence that this difference in sociability is rooted in genetics?
Geneticist Bridgett vonHoldt [at Princeton University] looked through the dog genome and found areas that showed evidence of recent rapid evolution, which is to say impacts of domestication. There was one particular section of a dog chromosome where, in humans, the genes are implicated in Williams-Beuren syndrome. This syndrome has many impacts but one is exceptional gregariousness. From DNA samples taken from dogs and wolves, it turned out that three of the genes involved in Williams syndrome are correlated with this difference in the behaviour of dogs and wolves.

You mention experiments where dog owners pretend to have a heart attack or are pinned down by a bookshelf. Their dogs didn't help!
I think those tests were too intellectually demanding. I mean, would you know what to do if somebody has a heart attack? What's the dog supposed to do if a bookcase falls on you? It's an absurdly demanding situation to put a dog into. But there are plenty of studies that show dogs will try to help. These are things people can easily do for themselves: pretend to cry and you will see dogs show all sorts of signs of distress. In new experiments that my student Joshua Van Bourg and I have been doing, we have people climb into a box that can be easily opened and then cry out in distress. Sure enough, the dogs come and open the box.

Can science really demonstrate that our dogs love us?
Whatever definition of love you come up with – in scientific study, we talk about affiliation, gregariousness, contact, concern about being separated from a loved one – your dog loves you. You know, my mother of all people is sceptical about this. She says it's just because you feed them. So, is there space for scepticism? Yeah, sure. But if you are willing to accept that there is any individual in your life who loves you, then I think you have to accept that your dog loves you. By whatever measures we can use – hormones, brain waves, physiology, behaviour, whatever evidence you require to convince you that something loves you – your dog fulfils those criteria. ▮

Tiffany O'Callaghan is head of features for *New Scientist*

If you live in the US and would like to volunteer your dog to take part, please visit dogagingproject.org

Herding cats

Dogs aren't the only pets to be proposed to help the study of ageing: cats have also been put forward. But as might be expected, they aren't as amenable as dogs. "There are a couple of challenges with cats," says Daniel Promislow of the Dog Aging Project at the University of Washington in Seattle. "They don't show as much diversity as dogs and they tend to be longer-lived so it's a harder study – we'd have to wait longer to see patterns emerging."

Nonetheless, a project called Darwin's Ark, a pet citizen science project led by researchers at the Broad Institute of MIT and Harvard, is recruiting cats for a genetics project that could eventually produce insights into human ageing.

Dog years

It is often assumed that a calendar year is equivalent to seven "dog years", so that a dog's life expectancy is about a seventh of a human's. This is inaccurate for two reasons. One is that dogs reach sexual maturity much earlier in their lifespan than we do. The other is that different breeds of dog have different life expectancies (see "Live big, die young", page 40). As a rule, larger breeds die sooner – a common pattern in animals, though a paradoxical one given that larger species such as humans tend to live longer than smaller ones such as mice. Small dogs live on average for about 15 years but big dogs only 10. Cats typically live for 15 years.

FSTOP IMAGES/WINNIE AU/GETTY IMAGES

Anti-ageing treatments might even make your dog more affectionate

of these are consistent with what is known about mice treated with rapamycin: they don't just live longer but age more healthily, enjoying more disease-free months as well as more months overall. In gerontology circles, this extension of "healthspan" is seen as more desirable than merely adding extra years.

Based on the success of the first trial, Kaeberlein started a longer one in 2018, with dogs treated for six months and then followed. The trial is due to finish about now. It focused mainly on cardiac health but also measured the dogs' activity levels using special canine "Fitbits". It also assessed cognitive function to see whether rapamycin can help old dogs learn new tricks. Assuming the results are good, the full-scale trial will follow.

If TRIAD turns out to be barking up the right tree, it would be a step towards getting rapamycin approved as an all-purpose anti-ageing drug in humans – though whether the dog data would be taken into account by drug regulators isn't known, says Kaeberlein. Even if it fails, TRIAD will pave the way for future anti-ageing trials. "I view it as a proof of principle for how to test other interventions," says Kaeberlein, who has three dogs himself but hasn't volunteered them for the trial because of conflicts of interest. "Rapamycin is arguably the best we have now and the one to move forward with first, but there are other interventions that could be tested in the future. We're going to learn a lot about which measures of ageing in dogs are most useful, and provide measures for other people to test."

Even if the drug extends dogs' lives, nothing lasts forever. "One thing that keeps me a little bit awake at night is that, because of the way the study is designed, dogs are going to die during it," says Kaeberlein. In the current trial, they expect about two-thirds of the dogs to die during the three-year follow-up. "That's what gives us the statistical power to see any change in lifespan. But I do worry about how we manage owners' expectations and help them understand that, you know, your dog is old and this is not going to ensure anything. This is why we're doing the study to find out."

Other dog ageing projects are already up and running. In Denmark, for example, a team at the University Hospital for Companion Animals in Copenhagen is turning to pet dogs to study age-related cognitive decline. Old dogs can get a form of dementia called canine cognitive dysfunction (CCD), which is similar to Alzheimer's disease. "CCD is a good model of sporadic Alzheimer's disease in humans," says veterinary neurologist Barbara Blicher Thomsen. One goal is to identify brain changes in dogs that could be treated with drugs. "Our overall objective is to investigate the disease for the benefit of both the dogs and humans."

One thing is for sure – these projects won't have any problem recruiting volunteers. "Owners are very enthusiastic," says Promislow. "They love their dogs and they're excited to understand how they might be able to give them a longer and healthier life. The benefits are not just for the dog but also for the owner, they get more healthy years together."

Graham Lawton (@GrahamLawton) is a staff writer at *New Scientist*

GETTY IMAGES

Under Pressure

If you're going to try turning hydrogen into a metal, the first thing you will need is a thick skin, says **Michael Brooks**

WHO would have imagined that the world's greatest wonder material could generate so much heat? Unfortunately, it isn't the useful, thermal kind of heat. Or at least, not yet. After more than 90 years of attempts to create hydrogen in metallic form, the only verifiable output has been friction between those looking for it.

Being the first to produce metallic hydrogen would be a major achievement. So major that multiple groups of researchers have already claimed success. But their rivals are highly sceptical. The response to the latest claim, published in June, is typical. "This paper is much ado about nothing," says Ranga Dias at the University of Rochester in New York. You might think that is harsh, but it is exactly what the authors of the new paper said about his own claim from 2017.

All this aggravation comes from the fact that the stakes are so high. Metallic hydrogen's advocates claim that this version of the common element could revolutionise science and technology. For one thing, it could be a breakthrough rocket fuel, with its conversion back into molecular hydrogen releasing enormous amounts of heat. Then there are the big hopes of planetary scientists: the cores of gas giants like Jupiter are thought to be composed of the stuff. If we could make it in the lab, we might be able to understand how these planets form. Perhaps most enticing of all is metallic hydrogen's rumoured ability to superconduct at room temperature, allowing electricity to flow without energy losses.

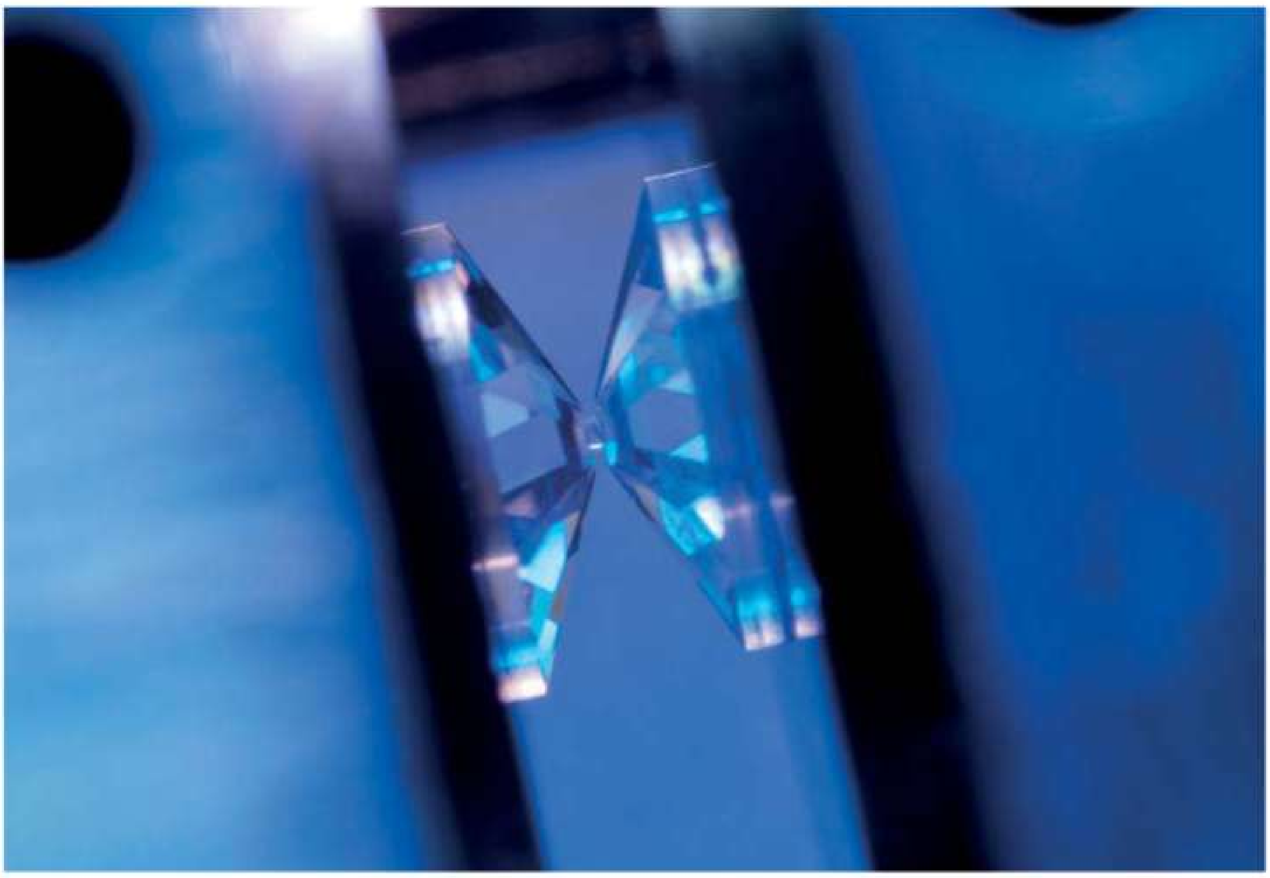
For all these reasons, a successful experiment would be a big deal, says Helen Maynard-Casely at the Australian Centre for Neutron Scattering. "I imagine they all hope they may get a Nobel prize."

The potential seems pretty sweet. So how did things get so bitter?

It all begins with hydrogen, the most abundant element in the universe. It is also the simplest, consisting of a single electron orbiting a proton. That single electron places it in the first column of the periodic table with alkali metals such as lithium, sodium and potassium. These three elements exist on Earth as solids capable of conducting electricity, whereas hydrogen is commonly found as a gas. To turn it into a metal, you would have to get its individual atoms to pack together tightly enough for their electrons to become "delocalised", that is, free to move around the material and thus conduct electricity.

Mounting pressure

The first people to realise that such a transformation might be possible were Eugene Wigner and Hillard Bell Huntington in 1935. They predicted that all hydrogen needed in order to behave like its neighbours in the periodic table was pressure – a lot of pressure. Enabling the electrons of hydrogen's atoms to break loose from their protons and instead roam around the rigid lattice of a solid would take nearly 400 gigapascals (GPa), equivalent to 4 million times atmospheric pressure (or a jumbo jet balanced on a pinhead). Achieving these pressures in the lab is challenging, to say the least. "Getting to pressure in excess of 100 GPa is very much a specialist thing," says Maynard-Casely. "Only a handful of groups are able to do this routinely."



MAX ALEXANDER/SCIENCE PHOTO LIBRARY

The first time we got close enough was in 1998. A team of engineers at Cornell University in New York and the University of Maryland squeezed hydrogen samples in what is known as a "diamond anvil". Essentially, this is a pair of diamonds shaped so that their tips are ultra-sharp, about one-quarter of the diameter of a human hair. Although tiny, these tips can trap some hydrogen between them. Then researchers turn a screw to push the two diamonds together and compress the trapped hydrogen. Eventually, after breaking 15 pairs of diamonds, the team managed to crank the pressure between the tips up to 342 GPa, approaching the pressure at Earth's core. According to theory, this should have been about enough to turn the hydrogen metallic. It wasn't.

Four years later, a team led by Paul Loubeyre of the French Atomic Energy Commission (CEA) near Paris showed that this was to be expected. The calculation of the pressure at which metallicity occurs is based on a measure of the "gap" between two very different energy states available to the electron in the hydrogen atom. As the pressure rises, the gap shrinks. This changes the way the electron is able to absorb or emit light. Just before the gap closes and the material becomes metallic, the hydrogen's electrons absorb light, but don't emit it – this causes the material to become increasingly opaque. But once the gap is closed and the electrons are able to exist as free-moving electrical conductors, they will re-emit absorbed light energy, making the material highly reflective. Extrapolating from their observations, Loubeyre and his colleagues reckoned that to create metallic hydrogen you would need pressures of about 450 GPa.

It took another 13 years, but we got there. In fact, we got to 495 GPa, and saw metallic hydrogen. At least, that is what Dias and Isaac Silvera, both then working at Harvard University, claimed in a 2017 peer-reviewed paper in the journal *Science*. Harvard issued a press release in which Silvera called their achievement "the Holy Grail of high-pressure physics".

Not so fast, said Loubeyre. "I don't think the paper is convincing at all," he told the equally famed journal *Nature*. That's because the claim of metallicity is based on a measure of the hydrogen's reflectivity: at 495 GPa it went shiny. But this could have happened for other reasons, says Loubeyre, such as the aluminium oxide coating on the diamond tips altering the hydrogen's reflectivity under pressure.

The pressure attained was also extrapolated from a calibration based on the way that diamond vibrates at high pressures, rather than measured directly. This has failed to convince other researchers, who have suggested the pressure might have been no more than 350 GPa.

Mikhail Eremets at the Max Planck Institute for Chemistry in Mainz, Germany, agrees that the Harvard claim isn't yet proven. In a

Diamond anvils can achieve pressures higher than those at Earth's core

> **"It would be a big deal. I imagine they all hope they may get a Nobel prize"**

response posted to the arXiv preprint server – a repository of scientific papers that haven't yet undergone peer review – he and his colleague Alexander Drozdov said "we find no convincing evidence for metallic hydrogen in their published data". They know what they are talking about – they, too, are attempting to make metallic hydrogen. As well as citing the possibility that the reflectance change came from the coating on the diamonds, the pressure measurement was "ambiguous", they said. It is obvious what needs to happen now: repeat the experiment. But that is easier said than done because the experiment self-destructed.

Dias and Silvera had always worried that their sample was fragile, which is why they limited the number and range of measurements they carried out. It had been more important, they felt, to publish their landmark results. But when they returned to carry out further investigations, they discovered that the sample was gone. Two years later, they still don't know what happened to it. The sliver of metallic hydrogen – if that's what it was – was just 10 micrometres thick. It might have slipped out of the anvil's jaws and been lost at the bottom of the apparatus. Or it might have just evaporated. But they stand by their claims. "We have answered all of the criticisms," says Silvera. Dias agrees. "We are very confident that we observed metallic hydrogen," he says.

The dispute has left the door open for a definitive sighting of metallic hydrogen – and Paul Loubeyre and his team have slipped in to take the prize. Or they would have done if anyone was willing to hand it over.

In June, Loubeyre posted a bold claim on arXiv. Entitled "Observation of a first order phase transition to metal hydrogen near 425 GPa", the paper was co-authored by Loubeyre's CEA colleague Florent Occelli and Paul Dumas of the French Synchrotron SOLEIL research facility. "Here," it says, "we show a [...] phase transition near 425 GPa from insulator molecular solid hydrogen to metal hydrogen." They were able to achieve this pressure, they say, because of a new kind of diamond anvil that Occelli had helped to develop.

By now, you won't be surprised to learn that the other teams have cried foul. Eremets reckons the observations are interesting, but far from conclusive. Dias is equally dismissive.

To prove the existence of a metallic state, it is necessary to demonstrate one of two things, says Dias. The first is that electrical conductivity remains finite as the temperature heads towards absolute zero. The second is to show that the material's reflectance increases with increasing wavelength. "Neither of these were shown," he says.

What's more, he adds, many of the reported observations have been seen before by other groups. Eremets also says that most of these "new" results have been reported before – some of them by his group. He is aggrieved that Loubeyre's preprint doesn't cite any of their work.

More light, less heat

New Scientist's attempts to contact Loubeyre and his colleagues for comment have gone unanswered, as have the questions raised by other researchers. For outside observers like Maynard-Casely, the only way to get definitive answers is to wait for their paper to be published in a peer-reviewed journal. "As a working scientist, I do have to defer to peer review," she says.

So where does this leave us? Will we have to wait another 90 years before we create the ultimate source of rocket fuel and the superconductor found inside Jupiter? Maybe not. Dias and Silvera claim to have repeated their experiment and observed the same result. "About a year ago, we reproduced a shiny sample at high pressure, but for technical reasons we were unable to measure the pressure, so we did not publish," says Silvera. Dias has since moved to the University of Rochester. "I am building a new lab with capabilities to make metallic hydrogen," he says. "I'm confident that we'll be able to replicate this work."

Not that everyone will be waiting with bated breath. It is time to move on, reckons Ashkan Salamat, who studies high-pressure systems at the University of Nevada, Las Vegas. "If we're not careful, we're going to have three or four people who end up just repeating each other's work, and each will claim they are first," he says. That, he adds, would be "a bit boring" when there is so much to explore. "The onset of metallisation seems pretty robust to me. What we don't know is if it's liquid or solid, or whether it could be a room temperature superconductor. There's plenty more to do: what we need now is to work together to answer these questions."

Michael Brooks is a *New Scientist* consultant based in the UK. @DrMichaelBrooks

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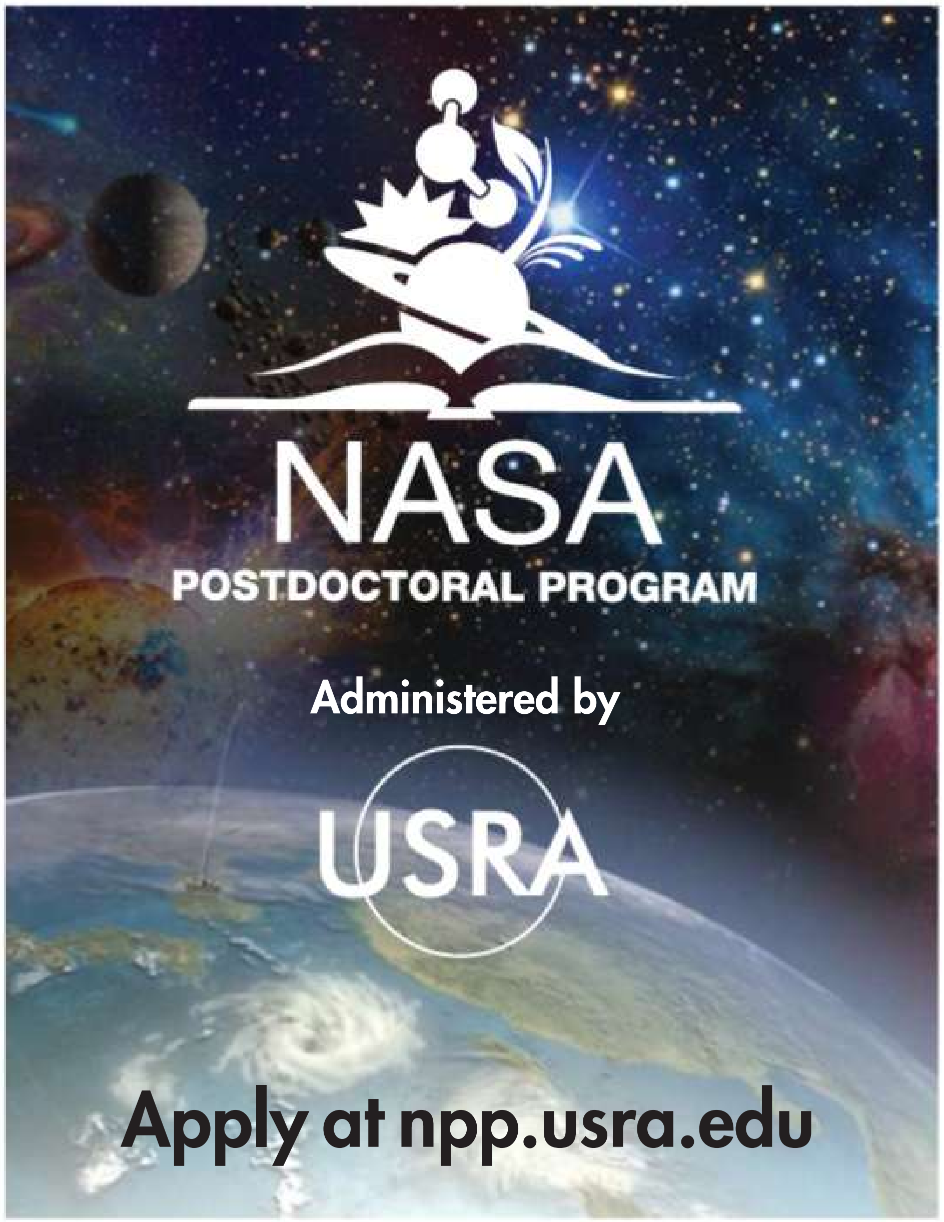

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Science of cooking Week 1

Know your onions

Bringing science to your kitchen can help you do amazing things, says **Sam Wong** – like making supremely good fried onions

Sam Wong is a digital reporter at *New Scientist*. Follow him @samwong1

What you need

Onions
A frying pan
Sodium bicarbonate

For next week

Milk
A thermometer
Rennet
A skimmer or slotted spoon
Cheesecloth

Next in the series

1 Caramelising onions
2 Making cheese
  Harness ancient biotechnology
3 The science of crispiness
4 Tofu and Sichuan pepper
5 Gravlax and curing
6 Tempering chocolate
7 Umami and flavour
8 Perfect pancakes
9 Kimchi and fermentation
10 Sourdough bread

JAMES WINSPEAR

Science of cooking online

Projects will be posted each week at newscientist.com/cooking Email: cooking@newscientist.com

WELCOME to this new series on the science of cooking. In the coming weeks, I will shed light on the amazing transformations that turn simple ingredients into delicacies, and explain how you can use science to make your food taste even better.

Let's start where so many recipes begin, with frying onions. A typical recipe will ask you to cook onions until they are soft and brown, often claiming that it takes about 10 minutes. If you have ever tried it, you will know this isn't true. Not by a long shot. It takes around 40 minutes to get properly dark, sweet-tasting onions.

But with a little knowledge of what is happening in the pan, you can halve this time and still get great-tasting onions.

The first thing that happens when onions cook is that the water inside the cells vaporises. The cells then burst, releasing sugars, proteins and a variety of aromatic compounds that make your kitchen smell great.

Heat breaks down larger sugar molecules into smaller ones such as glucose and fructose, increasing the sweetness. These sugars fragment and recombine into hundreds of new molecules, creating sweet, sour and bitter tastes, in a process called caramelisation.

The proteins break down into their constituent amino acids, and it is when these react with sugars that the really delicious flavours start to emerge in what are called Maillard reactions. These produce a huge range of compounds and are behind the appetising colour and complex taste of many foods, including seared steak, dark beer and crusty bread.

All this takes time, gentle heat and stirring: if the pan is too hot or you leave some onions in contact with the surface of the pan for too long, they will produce bitter-tasting compounds before the centres have softened.

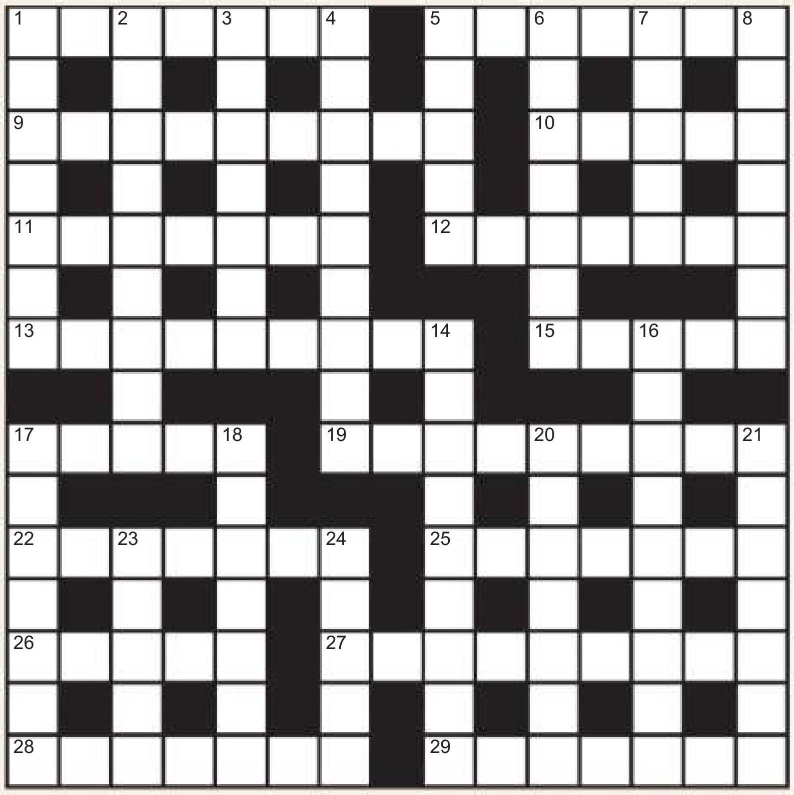
There are two ways to speed up the process. First, add alkali. Maillard reactions go faster in higher pH conditions. A dash of sodium bicarbonate (baking soda) will make onions brown much more quickly. It also weakens the pectin in their cell walls, so more cells rupture and release their contents. Don't overdo the bicarb or you will get mushy onions with an unpleasant soapy taste – a quarter of a teaspoon will do for two or three onions.

Second, adding water allows you to raise the heat without burning. Water also dissolves any brown compounds stuck to the pan and spreads them evenly through the onions. You could also use wine or stock if you prefer.

With these cheats, you can get soft, rich, dark brown onions in about 20 minutes. Mix them with crème fraiche to make an irresistible caramelised onion dip or use them as a base for onion gravy or soup.

Next week, I will show you how to harness ancient biotechnology to make cheese. ▮

Quick crossword #48 *Set by Richard Smyth*



ACROSS

1 India's National Institute of Science, Technology and Development Studies (7)
5 Social network, founded 2006 (7)
9 Logical impossibilities (9)
10 University city, once home to Galileo (5)
11 Valve (or vacuum tube) with four electrodes (7)
12 Plant genus in the family Saxifragaceae (7)
13 Inability to feel pleasure (9)
15 Intelligent – like a phone or motorway? (5)
17 Early programming language (5)
19 Sans-serif typeface (9)
22 University city, once home to Carl Linnaeus (7)
25 Of a polygon, having equal sides and angles (7)
26 Root used as a perfumery fixative (5)
27 London borough on the prime meridian (9)
28 Of a fruit, to split open (7)
29 Booting (5,2)

DOWN

1 Flammable liquid hydrocarbon mix (7)
2 Extends; expands (9)
3 Human-like automaton (7)
4 0.0625 (9)
5 Nikola ___, Serbian-American inventor (5)
6 Moon of Saturn (7)
7 ___ barrage, dam-like energy structure (5)
8 Substance that causes a reaction (7)
14 Pollen, nickel and peanuts, perhaps (9)
16 Obliquity (in terms of astronomy) (5,4)
17 Guion ___, first African-American to go to space (7)
18 Body of a vehicle (7)
20 Plant genus to which the rainforest plum belongs (7)
21 Vessel such as the USS Akron or the Hindenburg (7)
23 Freshwater fish (5)
24 Vertex (5)

Answers and the next cryptic crossword next week

Quick quiz #33

1 Originally named after a brand of washing powder, the axion could clean up what massive problem in fundamental physics?

2 NASA's Messenger probe orbited which solar system planet between 2011 and 2015?

3 Named after their toxin-firing cnidocyte cells, where might you expect to see animals of the phylum Cnidaria?

4 Toxic acetaldehyde, the most abundant carcinogen in tobacco smoke, can crop up fleetingly in our bodies even if we don't smoke. Where and as a result of what?

5 Devils Tower in Wyoming – the first US National Monument – is a fine example of what geological feature, defined as an isolated hill with almost vertical sides?

Answers below

Quick quiz #33
Answers

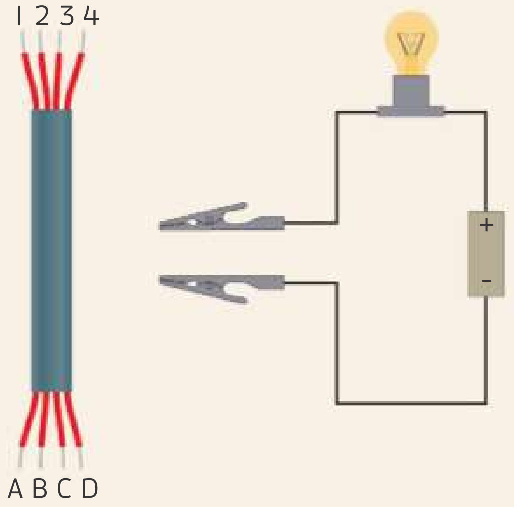
1 The nature of dark matter: it is a hypothetical particle whose existence could explain some or all of the universe's missing mass
2 Mercury
3 Underwater, especially in the sea. The phylum includes corals, jellyfish and sea anemones
4 In our liver, as part of the chemical breakdown of ethanol following the consumption of alcoholic drinks
5 A butte

Puzzle *set by Rob Eastaway*

#40 Light bulb moment

A tall office building is being rewired. There is a staircase, but the lift is out of action.

There are four identical-looking wires, A, B, C and D, feeding into a pipe in the ceiling of the basement. You are reasonably confident that it is those same four wires that emerge from a pipe on the top floor. Unfortunately the wires have become tangled, so it isn't known which wire becomes 1, 2, 3 or 4.



To find out, you can join two wires together in the basement (for example A and C) and you can attach two wires at the other end to a light bulb and battery (for example 1 and 3). If the bulb lights, you have made a circuit.

Starting in the basement, what is the smallest number of light bulb flashes that you need in order to figure out which wire is which? And how many times do you need to climb the stairs?

Answer next week

Our crosswords are now solvable online
Available at newscientist.com/crosswords

Taylor-made odds

What were the chances that Feedback would kick off 2020 with a story about probability? No, scratch that – what were the chances that Feedback would kick off 2020 with a joke about probability inspired by a story about probability? Who cares, right? When it comes to statistics, the only numbers anyone cares about are the ones that win you the lottery. Or at least that's certainly true for John Cabral of Maryland, who has hit the jackpot not once but twice.

What could account for this outrageous stroke of good fortune? None other than the pop sensation Taylor Swift, according to Cabral. On the day of his first victory, he was working at one of Swift's concerts, helping her get to a stage on the Potomac river by boat. And his second win? Well, get this – it came two days before she picked up six gongs at the American Music Awards. "A coincidence?" Feedback breathlessly asks itself. "Yes," we answer, having recovered our puff, "and not an altogether surprising one at that."

This art is bananas

Science and art are two separate cultures, said the novelist C. P. Snow, lamenting how few artists had ever heard of the laws of thermodynamics compared with how many scientists knew Shakespeare. He dreamed of a world where everybody took equal interest in both, which sounds great in principle, but terrible if you have standing tickets at London's Globe theatre for a 3-hour lecture on entropy. Things are marginally better today, if only because nobody in either culture has heard of C. P. Snow, and so this tiresome debate has quietly heat-deathed itself into oblivion.

A renewal of hostilities between the cultures recently caught Feedback's attention, however, and well and truly got our dander up. A few weeks ago, artist Maurizio Cattelan took the world by storm by taping a single banana to a wall at the Art Basel show in Miami Beach, Florida, and selling the resulting installation, called *Comedian*, for $120,000. As art largely consists of communication by means other than direct speech, the resulting wall-to-banana-flavoured-wall coverage was undoubtedly a success.

To wit, the Twitter account of Imperial College London soon entered the debate. As an institution of higher learning devoted almost exclusively to science and engineering, Imperial is often touted as the UK's answer to MIT – though maybe if people took more interest in the humanities, Feedback ponders, they would realise MIT isn't a question. In a series of tweets broadly dismissive of artistic endeavour, it posted pictures of bananas affixed to various on-campus surfaces with the message "spot the art".

Given that the original banana was able to defy the laws of gravity with the help of highly engineered material adhesives, we disagree with Imperial's assessment. If anything, the original work was science. Stick that in Magritte's pipe and smoke it.

Art of darkness

More arty news courtesy of Madrid, where the Prado Museum has collaborated with conservation group WWF to imagine what some of its iconic masterpieces would look like in a world where global temperatures had risen by 1.5°C. The results are not an improvement. An enormous oil painting of Philip IV of Spain on horseback by Diego Velázquez, for example, now shows the king and his steed going for a swim.

As gimmicks go, it has merit. Perhaps a similar overhaul is necessary to bring great works of literature in line with the apocalyptic future. In a revamped *Moby-Dick*, for example, Captain Ahab's cetacean nemesis would have long since choked to death on microplastic filaments. *War and Peace* would find Napoleon mopping his sweaty brow in the balmy Russian winter, having conquered the snow-free steppes with little difficulty. And in an updated *Northern Lights*, Lyra travels north to find the once-mighty armoured bears drifting listlessly on ice floes. C. P. Snow would surely approve – or should that be C. P. Slush?

Ten-microgallon hat

The Good, the Bad and the Ugly, for readers who have been led astray on such matters, is not a movie about pigeons. It is a movie about cowboys – that is to say, misogynistic, murdering, rootin'-tootin' gunmen who meander about the 19th-century American Wild West in search of a credit sequence. It takes them a while to find it, but lordy are you relieved when they do.

It would probably have aged better had it been about pigeons, which is why, to make an abrupt segue, Feedback's interest was piqued by news out of Las Vegas, Nevada, that a trio of pigeons were wearing cowboy hats.

The story gets more depressing the more you find out. It seems that some ornithological milliner glued the aforementioned hats to the aforementioned pigeons, perhaps to coincide with the National Finals Rodeo taking place in the same state.

But perhaps things aren't as bad as they seem. Charles Walcott, an ornithologist at Cornell University in Ithaca, New York, told *The New York Times* he wasn't concerned for the birds' welfare. "They look like happy pigeons to me," he said. "It is hard to know, of course, because they will not talk to us." Looks like we've got ourselves an avian stand-off. ▮

Twisteddoodles *for New Scientist*

This newly emerged butterfly at its most vulnerable
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#TRANSFORMATION
When composing its first social media post about its new look.
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MIKE ROBINSON/ALAMY STOCK PHOTO

Is the second wind that long-distance runners get real or imagined?

This week's new questions

Running on empty **Many runners experience a "second wind". Is this a real, measurable phenomenon or a psychological effect?** ***Robert Cy Jones****, East Grinstead, UK*

Water effect **Water usually reduces friction between two surfaces. So why is it more difficult to put on socks and gloves when your feet and hands are wet?** ***Jim Beattie****, Glasgow, UK*

Burning hot

Are all flames the same temperature? If not, what causes their temperatures to vary?

Elizabeth Bromham
Kallista, Victoria, Australia
Flames are created when two gases react to produce heat and light. Different reactions produce different quantities of heat so, no, not all flames are the same temperature. Anyone who has passed their fingers unscathed through a yellow candle flame but been burned by the blue flame of a gas stove will have found this out.

Rob Leah
London, UK
Flames can vary in temperature from about 600°C to more than 3000°C. One factor is the energy released from the fuel's combustion. Acetylene, for example, burns very hot because of the triple bond between the carbon atoms in it.

Other factors increasing flame temperature include using pure oxygen rather than air, having just the right amount of oxygen to ensure complete combustion of the fuel, and low heat radiation to the surroundings. Blue flames are normally hotter than luminous flames like that of a candle, because in a luminous flame, carbon particles formed in incomplete combustion radiate energy away as infrared radiation and visible light.

All of this explains why oxyacetylene flames are used in torches for welding and cutting: the flame produced burning acetylene in pure oxygen is hot enough to melt steel.

John Rowland
Derby, UK
Flames exist because atoms or molecules holding high-energy outer electrons react with each other. This means they exchange electrons and settle down as stable molecules. The electrons are liberated from chemical bonds, and although the resulting molecules may be stable, they are moving at high speeds, so they are hot.

Conventional domestic flames for heat and light tend to reach between about 800°C and 1000°C. Acetylene burned in oxygen can get to almost 3500°C thanks to the concentration of very active electrons that holds its carbon triple bond together. The carbon atoms combine with incoming oxygen atoms at very high speeds, releasing supersonic carbon monoxide molecules, which in turn form carbon dioxide. All this velocity adds up to lots of heat in a very small volume.

Dead before his time

I have just read *Poor Little Warrior*, a short story about a man who time travels to the dinosaur era, dies there and is fossilised. Can we be sure hominin fossils haven't met a similar fate?

Andy Howse
Taunton, Somerset, UK
Albert Einstein's theories don't preclude time travel, but should it be possible, it will be travel in time only, not in space.

If you build a time machine and set the controls for six months in the future, in the meantime Earth will have rotated on its axis 182.5 times, and will have moved halfway around its orbit. The distance from Earth to the sun is about 150 million kilometres, so when you arrive six months in the future, Earth will be some 300 million kilometres away from you. Even if you set the dial for a year, you wouldn't end up in the same place in space because the sun is in orbit around the galaxy.

Travelling through time and remaining in the same location on Earth just isn't possible.

Richard Swifte
Darmstadt, Germany
The chances of a creature from the dinosaur era – be it dinosaur or time traveller – being fossilised are very low. In most environments, a dead body is exposed to scavengers and bacteria, and most soils are acidic and will eventually dissolve bones. Dinosaur-era fossilisation best occurs either when the corpse was quickly buried in the protective sediment of a river or lake, or in arid regions where it dried out and was less prone to scavenging or bacterial attack.

Factor in the chance of actually discovering fossils that do exist, and the likelihood of finding the fossils of any time-travelling hominins is remote (assuming that relatively few travellers ended their lives in the dinosaur era).

More possible would be finding traces of people's clothes, tools, ornaments or even buildings. Any hard non-organic objects could leave recognisable traces for a long time. Perhaps there is the remains of a 100-million-year-old rubbish dump waiting to be discovered?

Hillary J. Shaw
Newport, Shropshire, UK
I think it was physicist Stephen Hawking who asserted that time travel to the past was impossible because of a positive feedback process akin to microphone "screech", when a signal feeds back to the emitter and amplifies itself. Anybody going to the past must transport some energy back, in the form of heat, matter and so on.

Fast forward millions of years, and that energy reaches our time again. The accumulated feedback can end up destroying the system. This effect may be how the universe is protected from paradoxes such as killing your own grandparents when they were children. ▮

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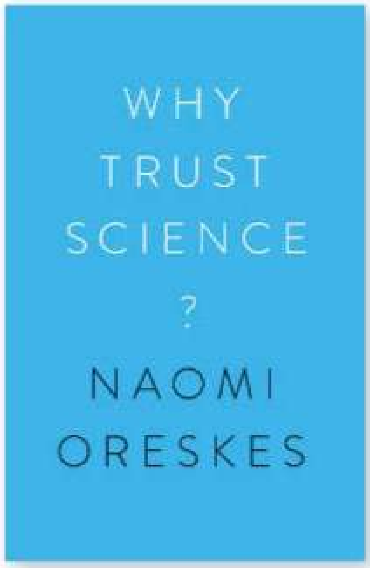

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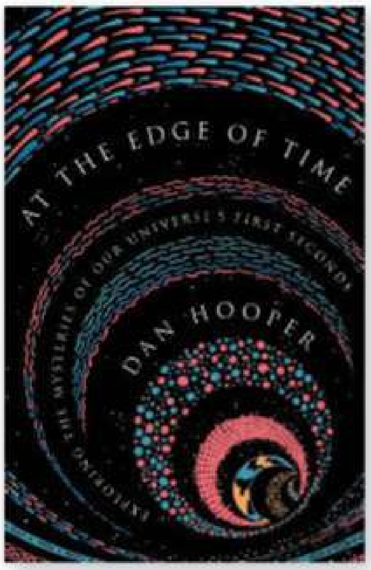

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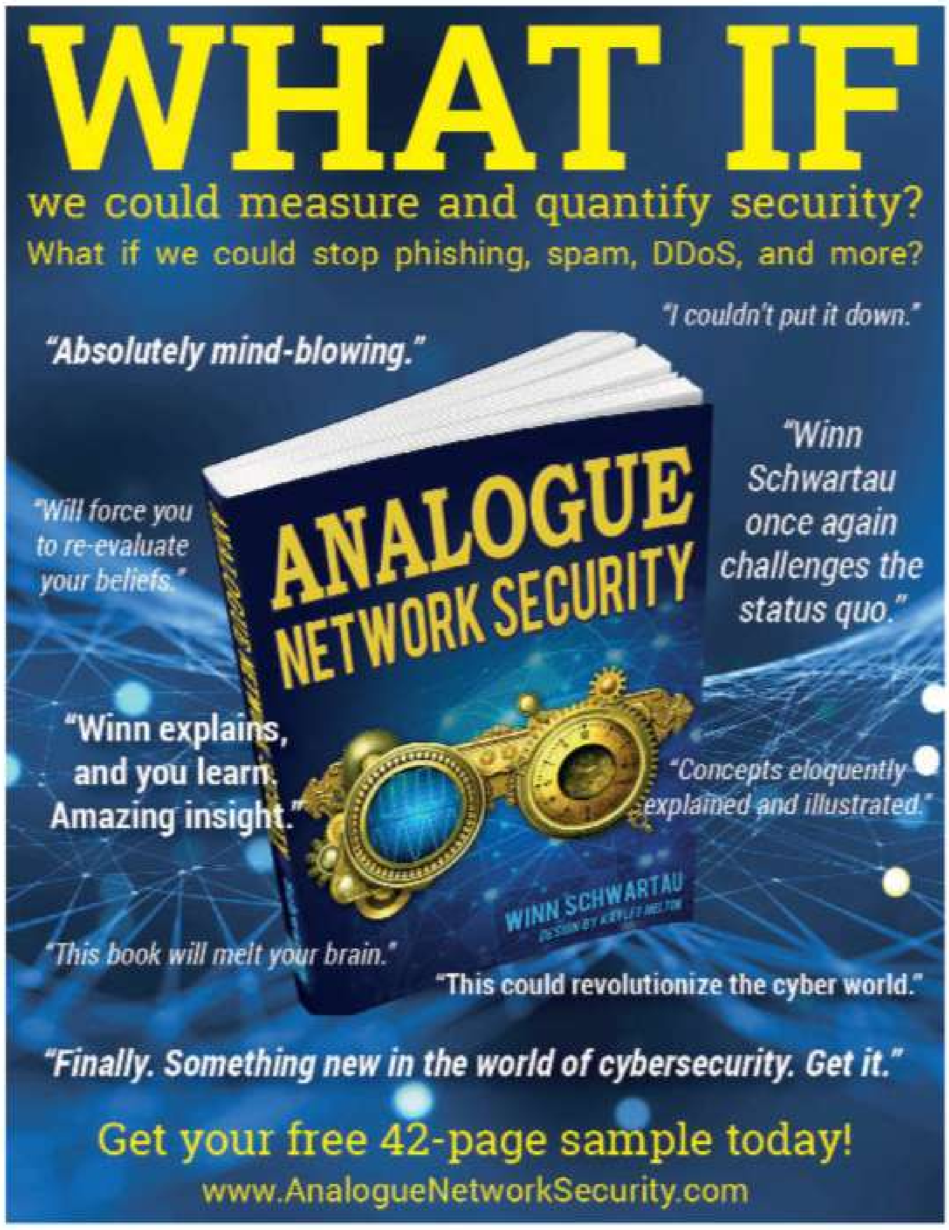
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Although the search for extraterrestrial intelligence has drawn a blank so far, we are getting better at it all the time, says SETI expert **Jill Tarter**

As a child, what did you want to do when you grew up?

At age 8, I wanted to be an engineer because it was the most male profession I knew about. At the time, my mother thought I should spend more time with her, rather than hunting and fishing with my dad, so I could learn about "girl things". I was furious!

Explain your work in one easy paragraph.

We are searching for extraterrestrial intelligent life, but we don't have any way of detecting intelligence across the vast distances that separate the stars. So we use large telescopes to try to observe how distant technologies may have modified their environment in ways that we can observe, and we also attempt to detect signals that may have been sent in our direction.

What do you love most about what you do?

I love trying to figure out how to do our search better and faster and in new ways. I also love to talk about what I do with people all over the planet. If we all see ourselves as Earthlings, then it may be possible to cooperate on a global scale to solve the enormous challenges we face.

How did you end up working in this field?

It was an accident. When I was a student, I learned how to program the University of California, Berkeley's first desktop computer. Many years later, the computer was donated to Stuart Bowyer to use in a SETI project. He didn't know how to use it, so he recruited me. The opportunity to try to answer this huge question about extraterrestrial life hooked me and I've stayed hooked ever since.

Were you good at science at school?

Yes. I was lucky to have a great physics teacher who also substituted for my dad, who died when I was 12.

How has your field of study changed in the time you have been working in it?

There have been two major game changers: exoplanets and extremophiles. When we started, we had no idea whether other stars had planets. Today, we know that planets are everywhere. We also thought that the conditions that could support life were those that humans enjoy. But we have explored the most extreme environments on Earth and been astonished to discover life everywhere we look, as long as there is liquid water. This suggests there is a lot of potentially habitable real estate out there.

Which discovery or achievement do you wish you'd made yourself?

The discovery of 51 Pegasi b, the first exoplanet around a sun-like star.

If you could have a conversation with any scientist, living or dead, who would it be?

It has to be Albert Einstein. I'd love to understand how he could invent new physics just by doing thought experiments.

What scientific development do you hope to see in your lifetime?

I think the 21st century will be the century of biology on Earth and beyond. But that may be a bit longer than my lifetime.

What's the most exciting thing you've worked on in your career?

Actually carrying out the search at observatories around the world, and then building the Allen Telescope Array (pictured) in a way that has become a template for future large radio telescopes.

Do you have an unexpected hobby, and if so, please will you tell us about it?

I love to dance the samba with my husband.

What's the best thing you've read or seen in the past 12 months?

Stories of Your Life and Others by Ted Chiang. One of the short stories is the basis for the film *Arrival*. The idea that writing in circles, as the aliens do in this story, requires knowledge of the future is intriguing.

> "There is a lot of potentially habitable real estate out there in the universe"

How useful will your skills be after the apocalypse?

I'm hopeful that propagating the meme of being an Earthling will help prevent the apocalypse.

OK, one last thing: tell us something that will blow our minds...

You are literally made of stardust. ▮

Jill Tarter is chair emeritus for SETI research at the SETI Institute, based in Mountain View, California

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